# Climate Smart Agriculture

## Feed The Future - India Triangular Training
## International Training on "Climate Smart Agriculture"

*August 20 - September 03, 2019*


Editors

M. Vanaja, S.K. Bal, K. Nagasree, Narsimlu Boini, B.M.K. Raju, K.S. Reddy, J.V.N.S. Prasad, G. Ravindra Chary, Goldi Tewari, Mahantesh Shirur and B. Krishna Rao



Indian Council of Agricultural Research

ICAR-Central Research Institute for Dryland Agriculture (CRIDA)

National Institute of Agricultural Extension Management (MANAGE)

Water and Land Management Training and Research Institute (WALAMTARI)


MANAGE

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## Compendium of Lectures

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**International Training on "Climate Smart Agriculture"**
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***Cover page Design:*** A.V.M. Subba Rao

# Preface

The 37th Feed The Future-India Triangular Training (FTF-ITT) on "Climate Smart Agriculture (CSA)" is being organized during 20th August - 3rd September 2019. The program is sponsored by USAID representing United States and is being implemented jointly by National Institute of Agricultural Extension Management (MANAGE), ICAR-Central Research Institute for Dryland Agriculture (CRIDA) and Water and Land Management Training and Research Institute (WALAMTARI). The main objective of the program is to address human and institutional capacity gaps in Agriculture and allied sectors to achieve food and nutritional security, in twenty selected African (Botswana, Democratic Republic of Congo, Ghana, Kenya, Liberia, Malawi, Mozambique, Rwanda, Sudan, Tanzania and Uganda) and Asian (Afghanistan, Bangladesh, Vietnam, Cambodia, Lao PDR, Mongolia, Myanmar, Nepal and Sri Lanka) countries.

Weather continues to play a dominant role in agricultural production despite many technological advances made besides extreme events like drought, cyclone, hailstorm, unseasonal rain, heat/cold waves etc. Climate Smart Agriculture is nothing but the approach for developing agricultural strategies to secure sustainable food security under climate change. It is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. Therefore, in this training program, the main focus will be to apprise the participants about the current aspects of CSA, especially in the Indian perspectives.

This compendium is a compilation of lectures pertaining to agro-climatological applications, real-time contingency plans, on-field soil and water management measures, efficient crops and cropping systems, water harvesting measures, farmers' practices and Indian success stories etc. for practicing Climate Smart Agriculture. The lectures include practical experiences of ICAR-CRIDA, MANAGE and WALAMTARI. We believe that the information provided in this book will be useful for researchers, academicians, extension personnel and policy makers interested in Climate Smart Agriculture.

***Editors***

# Message

'Climate Smart Agriculture' is a much talked-about issue. Recently, we have been hearing in the news about the heat waves rising in the European continent, rampant floods in various regions of India and many other Asian and African nations. Climate is an ever-changing entity and we need to learn how to live and cope with it. Three things are very important in this regard: we should have sufficient data and records regarding the climate change on regional, national and global level; communication to the farmers about the changing weather is crucial; each country should have appropriate storage system and buffer stock of food grains that can be utilised in case of emergencies. Diversity in terms of agricultural production and practices will also facilitate the adaptation of current agricultural system for future challenges. Proper and advanced planning and strategies can shape resilience in the face of greater climatic variability.

Owing to the importance of this issue, an international training programme on the theme "Climate Smart Agriculture" is being organised under the Feed the Future India Triangular Training (FTF ITT). It's my pleasure to welcome the 27 officials from 12 Asian and African nations for this unique training program where enrichment of ideas by the trainers and participants from across the globe will help us to identify gaps and opportunities related to the impact of climate change in agriculture. This training is very unique in many respects. First, the participants for this program representing 12 different countries belong to diverse professional background and expertise. Secondly, for the first time in the series of FTF ITT programs, three institutes (MANAGE, ICAR-CRIDA and WALAMTARI) have come forward to collaboratively conduct the program. I appreciate these two apex institutions for their collaborative support in organising this program.

I am sure with such diversity from both the participants and the organisers will make this program a great success. This training is packed with relevant practical exposure and field visits. I hope that the participants will gain many valuable experiences from the various modules offered by the three organising institutions. I shall be mighty pleased if the participants can identify the best solutions to address the issues of Climate Change in their respective countries. We all are aware about the effect of climate change in general, but being able to come together to shoulder the responsibility of developing the associated coping strategies as a frontline stakeholder is a great responsibility. I express my gratitude to USAID India for entrusting us with such a noble cause through the FTF ITT initiative.

I again congratulate the organising team at MANAGE, ICAR-CRIDA and WALAMTARI for their endeavours for making this event a success and the participants who have taken this effort to add value to the event.

**Mrs. V. Usha Rani, IAS**
*Director General, MANAGE*

# Message

The Intergovernmental Panel on Climate Change (IPCC) in its fifth assessment report (AR5) stated that warming of the climate system is unequivocal and is more pronounced since 1950s. The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, and sea level has risen. Each of the last three decades has been successively warmer at the earth's surface than any preceding decade since 1850. Climate change poses many challenges to growth and development across the world. Frequent incidence of droughts and floods threaten realization of potential crop yields as well as the investments. Growing scarcity of natural resources, especially of water proves to be the most limiting factor. Occurrence of extreme climate events such as cold and heat waves are other important factors that limit agricultural productivity.

Climate Smart Agriculture (CSA) is an approach that guides actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. It tackles with three objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. It encompasses adapting to climate challenges in some regions and responding to opportunities offered by climate in others. Climate risks are best addressed through increasing adaptive capacity which can bring immediate benefits and also can reduce the adverse impacts of climate change.

Recognizing the importance associated with the issues of climate change in agriculture, National Institute of Agricultural Extension Management (MANAGE), Ministry of Agriculture and Farmers' Welfare, GOI in collaboration with ICAR-Central Research Institute for Dryland Agriculture (CRIDA) and Water and Land Management Training and Research Institute (WALAMTARI), Telangana State has taken an initiative to organize an International Training Programme on the theme "Climate Smart Agriculture" under the Feed The Future- India Triangular Training (FTF ITT) to build the capacities of the executives/officials from 12 countries engaged in development of agriculture and allied sectors. ICAR-CRIDA, since 2011, is leading the flagship programme of Indian Council of Agricultural Research (ICAR), "National Innovations in Climate Resilient Agriculture (NICRA)". The experiences and expertise gained so far under NICRA with strategic research in agricultural, animal and fisheries sciences and demonstration of resilient technologies in 151 climate resilient villages located in vulnerable districts across the country involving 41 ICAR research institutes, State Agricultural Universities, Indian Institute of Technology (Chennai), coordinated research centres of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) and Agrometeorology (AICRPAM) and 121 Farm Science Centres (Krishi Vigyan Kendras), will come handy towards making Indian agriculture resilient to climate change.

I profusely thank, Mrs. V. Usha Rani, IAS, DG, MANAGE for giving this excellent opportunity to share the learning experiences in climate smart agriculture with the distinguished participants from 12 countries. I also acknowledge the contribution of scientists of CRIDA in developing this training programme and bringing out training material. Further I hope this programme will add to the knowledge of Climate Smart Agriculture both to the participants and the resource persons.

**Dr. G. Ravindra Chary**
*Director (Acting), ICAR-CRIDA*

# Message

**WATER AND LAND MANAGEMENT TRAINING AND RESEARCH INSTITUTE (WALAMTARI)**

**(A society under Irrigation & CAD Dept., Government of Telangana)**

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Land and water management plays a key role in climate smart agriculture. Wide-scale implementation of climate-smart soil and water management practices could enhance climate change adaptation and mitigation. It takes immense pleasure to be a part of the Feed The Future – India Triangular Training (FTF- ITT) Program on Climate Smart Agriculture in collaboration with MANAGE and ICAR- Central Research Institute for Dryland Agriculture (CRIDA) from $21^{st}$ August, 2019 to $3^{rd}$ September, 2019. The three day module on "Land and Water Management strategies for climate smart agriculture" is organized at WALAMTARI from $22^{nd}$ to $24^{th}$ August, 2019. The major goal of this training module is to equip the trainees from twelve different countries with sustainable land and water management practices to mitigate and adapt to changing climate scenarios with a special emphasis on increasing the water use efficiency in agriculture. The present publication is compilation of lectures delivered in this training program.

The efforts of the training organizers and resource persons deserve appreciation in compiling the latest information and technological interventions on climate smart agriculture. The publication would be useful for practitioners and extension personnel who are into formulation and implementation of developmental initiatives for wide-scale implementation of climate-smart agricultural practices.

Place: Hyderabad

**Er. P. Shyamsunder,** M.Tech.
*Director General, WALAMTARI*

# Contents

# 1. Global and Country Climate Change Scenarios - Climate Smart Agriculture Concepts and Initiations

**G. Ravindra Chary, Director (Act.)**

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Climate change is one of the important areas of concern globally to ensure food and nutrition security to the growing population. As per the latest report, the global average temperature rise is 0.99°C (NASA, 2016) since pre-industrial time (1850). Global warming is likely to reach 1.5°C between 2030 and 2052 if it continues to increase at the current rate (IPCC, 2018). Warming greater than the global average is being experienced in many land regions and seasons and it is 2 to 3 times higher in the Arctic. The year 2016 ranks as the warmest year and 16 of the 17 warmest years in the 136 year record all have occurred since 2001. The number of cold days and nights has decreased and the number of warm days and nights has increased globally. Frequency of heat waves has increased in large parts of Europe, Asia and Australia. Global sea level has risen by 0.19 m between 1901 and 2010.

## Indian Context

The impacts of climate change are global, but countries like India are highly vulnerable as large population depends on agriculture. Seasonal climate change projections for India indicated that during *kharif*, and *rabi* minimum temperatures likely to increase in the range of 0.95-4.07°C (2020 to 2080) and 1.10-4.65°C (2020 to 2080), respectively in different Representative Concentration Pathways (RCPs) over baseline temperatures. Similarly, maximum temperatures during *kharif* to increase in the range of 0.74- 3.53°C (2020 to 2080) in different RCPs while the projected increase in *rabi* is 0.88-4.01°C (2020 to 2080). Projections are showing that temperature rise is going to be more in northern parts than in southern parts of India. *Kharif* rainfall is projected to increase in the range of 2.3-3.3% (2020), 4.9-10.1% (2050), while *rabi* rainfall is projected to increase in the range of 12% (2020) and 12-17% (2050). The $CO_2$ concentration are projected increase in the range of 419-432 µmol (2020), 441-572 µmol (2050) and 429 to 799 µmol (2080) in different RCPs. Studies in India showed significant negative impacts of climate change, predicted to reduce yields by 4.5 to 9.0%, depending on the magnitude and distribution of warming.

Aberrations in South-West monsoon which include delay in onset, long dry spells and early withdrawal, all of which affect the crops, strongly influence the productivity levels. The high inter and intra-seasonal variability in rainfall distribution, extreme temperature and rainfall events are causing crop damages and huge losses to farmers. Long term data for India indicates that rainfed areas witness 3-4 drought years in every 10-year period. Of these, 2-3 are of moderate and one may be of severe intensity. Although climate change is linked to exacerbation of droughts, so far no definite trend is seen on the frequency of droughts in India based on long term data. Each year, one or the other part in the country is affected by droughts, floods, cyclones, hailstorms, frost and other climatic events.

Climate change will have negative effects on irrigated crop yields across regions, including in India both due to temperature rise and changes in water availability, while rainfed agriculture will be primarily impacted due to rainfall variability and reduction in number of rainy days. In India, the impact of climate change on agriculture is expected to be more severe than realized earlier, particularly in crops like wheat. Yield decline are likely to be caused by shortening of growing period, negative impacts on reproduction, grain filling, decrease in water availability and poor vernalization. Biodiversity is also adversely affected which in turn affects agricultural production; this is particularly important to the marginal and small farmers in India. Wide spread deficiencies of macro and micro nutrients occur due to loss of nutrients through surface soil erosion and inadequate nutrient application.

## Climate Smart Agriculture - Indian Initiatives

To meet the challenges posed by climate change on the agricultural system, India has accorded high priority in understanding the impacts of climate change and developing adaptation and mitigation strategies. The Prime Minister's National Action Plan on Climate Change (NAPCC) established during the year 2008 and has identified agriculture as the priority area of eight National Missions in India. National Adaptation Fund for Climate Change (NAFCC) was established in August, 2015 to meet the cost of adaptation to climate change for the State and Union Territories of India that are particularly vulnerable to the adverse effects of climate change. Government has set up a budget provision of Rs.350 crores for the year 2015-16 and 2016-17, with an estimated requirement of Rs. 181.5 crores for financial year 2017-18 for NAFCC. The projects under NAFCC prioritize the needs that build climate resilience in the areas identified under the SAPCC (State Action Plan on Climate Change) and the relevant Missions under NAPCC.

National Bank for Agriculture and Rural Development (NABARD) has been designated as National Implementing Entity (NIE) for implementation of adaptation projects under NAFCC by Govt. of India. Under this arrangement, NABARD would perform roles in facilitating identification of project ideas/concepts from State Action Plan for Climate Change (SAPCC), project formulation, appraisal and sanction, disbursement of fund, monitoring & evaluation and capacity building of stakeholders including State Governments. So far, 27 projects have been sanctioned to different states in India with budget outlay of $95.8 Million.

## National Initiative on Climate Resilient Agriculture (NICRA)

The National Initiative on Climate Resilient Agriculture (NICRA) a flag ship national level project of ICAR was launched during XI Plan in February 2011, and is now renamed as "National Innovations in Climate Resilient Agriculture (NICRA)" in the XII Plan. This program has multi-disciplinary research teams across 41 ICAR institutes in the country covering all the sectors *viz.*, crops, horticulture, livestock, fisheries and natural resource management. The major objective of NICRA is to enhance the resilience of Indian agriculture in crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies; to demonstrate the site specific technology packages on farmers' fields for adapting to current climate risks; and to enhance the capacity (knowledge, skill and management) of scientists and other stakeholders in climate resilient agricultural research and its application.

Some of the major achievements so far in the project are development and standardization of state of the art infrastructure for climate change research, Preparation of first ever Vulnerability Atlas of India at district-level; Extensive phenotyping of germplasm and breeding in rice, wheat, maize, pigeon pea and tomato to multiple abiotic stresses; NRM technologies *viz*., Biochar, Conservation Agriculture (CA), water foot prints and emission reduction through efficient energy management; Standardization of the techniques for measurement of GHG emissions in different production systems; Mapping unique traits for thermal tolerance in livestock, invention of heat care mixture for poultry, development of several technologies by management of feed, breed and shelter to cope with climate change in livestock; Relationship were established between increase in Surface Sea Temperature (SST) and catch and spawning in major marine fish species. Simulation modeling was used to understand the climate change and impacts at regional/national level.

Location specific technologies which are developed by the national agricultural research system which can impart resilience against climatic vulnerability are being demonstrated in farmer participatory mode in the climatically most vulnerable districts of the country through 121 Krishi Vigyan Kendras (KVKs), 23 centres of All India Coordinated Research Projects on Dryland Agriculture (AICRPDA) spread across the country demonstrations of climate resilient technologies were undertaken to enhance the adaptive capacity and to enable farmers cope with current climatic variability. It is being implemented in 151 climatically vulnerable districts of the country spread across the country. A representative village in each climatically vulnerable district was selected for implementation. The interventions are broadly divided into four modules *viz.*, natural resource management, crop production, livestock and fisheries and creation of institutional structures for sustaining the activities envisaged and scaling up of interventions.

NRM interventions included site specific rainwater harvesting structures (RWH) in drought affected areas; recycling of harvested water through supplemental irrigation to alleviate moisture stress during midseason dry spells; improved drainage in flood-prone areas; conservation tillage; artificial groundwater recharge and water saving micro-irrigation methods were demonstrated. Through these RWH structures cropping intensity was increased by about 20%. Under the crop production module, demonstrations consists of drought and flood tolerant varieties, community nurseries for delayed monsoon, water saving paddy cultivation methods (SRI, aerobic, direct seeding), advancement of planting dates of *rabi* crops in areas with terminal heat stress, frost management in horticulture through fumigation, popularization of location-specific & risk-reducing intercropping systems with high sustainable yield index. Under the livestock & fishery module demonstrations on fodder production, especially under drought/flood situations, improved shelter for reducing heat stress in livestock, silage making methods for storage of green fodder and feeding during the dry season, breed selection and stocking ratios for fish production in farm ponds and monitoring of water quality in aquaculture and integrated farming system models in diverse agro ecosystems are being taken up. Village level institutional mechanisms such as Village Level Climate Risk Management Committees (VCRMC), custom hiring centers are established to improve the timeliness of operations during the limited window periods of moisture availability in rainfed areas and to promote small farm mechanization for adoption of climate resilient practices. These interventions helped farmers to reduce the yield losses and enhanced their adaptive capacity against climatic variability. Major aim of such initiative is to establish 151 climate resilient villages (CRVs) as model villages across the country for further up-scaling in the climatically vulnerable districts by respective State Governments and other developmental agencies.

# 2. National Innovations in Climate Resilient Agriculture (NICRA): A Flagship Network Project of Indian Council of Agricultural Research (ICAR)

**M. Prabhakar, Principal Investigator, NICRA**

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India; Email: m.prabhakar@icar.gov.in

Increasing impact of climate variability on agriculture is evident. Therefore, need for coping with current climate variability, preparing for future climate change is very crucial. It is also important to assess crop losses due to extreme events. The need for continuous data generation for identifying trends and building scenarios is also important. To meet the challenges of sustaining domestic food production in the face of changing climate and to generate information on adaptation and mitigation in agriculture to contribute to global fora like United Nations Framework Convention on Climate Change (UNFCCC), the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Government of India launched a flagship network project 'National Innovations in Climate Resilient Agriculture' (NICRA) during 2011. NICRA is the unique project which brings all sectors of agriculture *viz.*, crops, horticulture, livestock, fisheries, natural resource management (NRM) and extension scientists on one platform.

## Objectives

- To enhance the resilience of Indian agriculture to climatic variability and climate change through strategic research on adaptation and mitigation
- To validate and demonstrate climate resilient technologies on farmers' fields.
- To strengthen the capacity of scientists and other stakeholders in climate resilient agriculture
- To draw policy guidelines for wider scale adoption of resilience-enhancing technologies and options

## Mission

Enhancing the resilience of Indian Agriculture to climate variability and climate change through both application of improved technologies and new policies

## Vision

To develop and promote climate resilient technologies in agriculture which will address vulnerable areas of the country and the outputs of the project will help the districts and regions prone to extreme weather conditions like droughts, floods, frost, heat waves, etc. to cope with such extremes

## Components

The scheme involved components *viz.* strategic research through network as well as sponsored/ competitive grants mode, technology demonstration & dissemination and capacity building.

## Strategic Research

In the strategic research, both short term and long term research programs with a national perspective have been taken up involving adaptation and mitigation covering crops, horticulture, livestock, fisheries and poultry. The main thrust areas covered are (i) identifying most vulnerable districts/regions, (ii) evolving crop varieties and management practices for adaptation and mitigation, (iii) assessing climate change impacts on livestock, fisheries and poultry and identifying adaptation strategies. In the strategic research component, both short term and log term research programs with a national perspective have been taken up to evolve adaptation and mitigation strategies in crops, horticulture, natural resources, livestock, fisheries and poultry About 41 ICAR institutes representing different sectors of agriculture are undertaking climate change research in a network mode focusing the respective them areas.

Significant achievements of the project include extensive field phenotyping of germplasm of target crops (rice, wheat, maize, pigeonpea, tomato) to multiple abiotic stresses, preparation of first ever vulnerability atlas of India at district-level for all the 572 rural districts, technology development for climate resilient horticulture including inter-specific grafting of tomato, NRM in adaptation- Biochar, CA, water foot prints and emission reduction through efficient energy management, quantification of carbon sequestration by agro-forestry, quantification and techniques for measurement of GHG emissions in the rice-based system and marine ecosystem; quantification of carbon sequestration potential through agro-forestry systems across the country, Unique traits for thermal tolerance in livestock mapped, heat care mixture for poultry ready for commercialization, relationship established between increase in SST and catch and spawning in major marine fish species.

Research proposals addressing critical gaps not covered in the Strategic Research Component but have a major bearing of the productivity of principle commodities in the region are being funded through competitive and sponsored grants. So far, 18 sponsored and 33 competitive projects have been funded to undertake critical areas of climate change research.

## Technology Demonstrations

Under NICRA demonstrations of proven technologies were given to enhance the adaptive capacity and to enable farmers cope with current climatic variability. Location specific technologies which are developed by the national agricultural research system which can impart resilience against climatic vulnerability are being demonstrated. TDC is being implemented in 121 climatically vulnerable districts of the country through Krishi Vigyan

Kendras (KVKs) spread across the country. A representative village in each climatically vulnerable district was selected for implementation. The interventions are broadly divided into four modules *viz.*, natural resource management, crop production, livestock and fisheries and creation of institutional structures for sustaining the activities envisaged and scaling up of interventions.

NRM interventions included site specific rainwater harvesting structures (RWH) in drought affected areas; recycling of harvested water through supplemental irrigation to alleviate moisture stress during midseason dry spells; improved drainage in flood-prone areas; conservation tillage; artificial groundwater recharge and water saving micro-irrigation methods were demonstrated. Through these RWH structures cropping intensity was increased by about 20%. Under the crop production module, demonstrations consists of drought and flood tolerant varieties, community nurseries for delayed monsoon, water saving paddy cultivation methods (SRI, aerobic, direct seeding), advancement of planting dates of *rabi* crops in areas with terminal heat stress, frost management in horticulture through fumigation, popularization of location-specific & risk-reducing intercropping systems with high sustainable yield index. Under the livestock & fishery module demonstrations on fodder production, especially under drought/flood situations, improved shelter for reducing heat stress in livestock, silage making methods for storage of green fodder and feeding during the dry season, breed selection and stocking ratios for fish production in farm ponds and monitoring of water quality in aquaculture and integrated farming system models in diverse agro ecosystems are being taken up. Village level institutional mechanisms such as Village Level Climate Risk Management Committees (VCRMC), custom hiring centers are created for managing infrastructure created and to improve the timeliness of operations during the limited window periods of moisture availability in rainfed areas and to promote small farm mechanization for adoption of climate resilient practices. These interventions helped farmers to reduce the yield losses and enhanced their adaptive capacity against climatic variability.

## Capacity building

A large scale capacity building program on climate resilient agriculture is being undertaken with more than 1200 scientists, 450 research scholars and 100s of post graduate students are involved on climate change research and dissemination of climate resilient technology across the country.

These resilient practices are being adopted by communities and spreading beyond NICRA villages. In the past six years 14,407 training programs were conducted throughout the country under NICRA project to educate farmers on various aspects of climate change and resilient technologies, covering 3,72, 897 farmers so as to enable wider adoption of climate resilient technologies and increase in yields.

## Major outcomes

- Supported some of the policy issues in Maharashtra (BBF Technology), Million farm ponds (Andhra Pradesh / Telangana), Ground water recharge initiatives (Southern states), NABARD action plans in Assam, Odisha, Andhra Pradesh, Telangana etc.
- NICRA model village expansion in Maharashtra in the 4500 villages under world bank funded project (PoCRA) with a budget out lay of Rs 5000 crores,
- Vulnerability assessment map is being used by different Ministries and several NGOs/ CBOs.
- Green House Gas (GHG) inventory by NICRA partner institutes contributes to BUR reports and National Communications to UNFCCC.
- Contingency planning workshops organized every year in different states helps in preparedness to face weather aberrations.
- NICRA is also contributing to National missions like National Mission on Sustainable Agriculture (NMSA), Water mission, Green fund etc.

# 3. Weather Based Insurance Services for Climate Smart Agriculture

**P. Vijaya Kumar, Project Coordinator, AICRPAM**

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India; Email: vkpuppala@yahoo.co.in

Agriculture contributes to 17% of the Indian GDP and supports the livelihood of two-thirds of the population. Despite tremendous technological developments, vagaries of weather continue to plague the agriculture production. Agriculture production and farm incomes in India are frequently affected by natural disasters such as floods, cyclones, storms, heat and cold waves etc. Loss in crop production and farm income due to unexpected weather hazards is beyond the carrying capacity of resource poor farmers of the country. With the growing commercialization of agriculture, the magnitude of crop loss due to unfavourable weather hazards is increasing leading to suicides of farmers. The State and National governments on their part are coming to the rescue of farming community by implementing various relief measures like reduction or suspension of land revenue taxes, loan waiving, relief from calamity relief fund etc. As agricultural yields are highly variable due to vagaries of weather, crops have to be covered under agriculture insurance for compensating yield losses and reduce the poverty of farming community. In India, since 1972 agricultural insurance has evolved as an adaptation strategy to mitigate / manage weather related risks in agriculture. However, experiences with traditional agricultural insurance schemes have shown that this approach is not often suitable in developing countries. In recent years, weather index insurance contracts in agriculture have emerged as an alternative to traditional agricultural (or crop) insurance.

## Risks in agriculture

Agricultural risks can range from independent (like localized hail storms) to highly correlated or covariant (example: Price risks or widespread drought). Weather risks are broadly of two types *viz.* sudden, unforeseen events (thunder storms) and cumulative events occurring over extended period (example: drought). The adverse impacts of either of these two types vary according to the crop, crop variety and time of occurrence of the event. Some of the weather risks in agriculture are: Drought, excess rainfall or floods, high temperature, low temperature events like frost and freeze, high winds and hail storms etc. To design appropriate risk management policies, it is useful to understand strategies and mechanisms employed by producers to deal with risk, including the distinction between informal and formal risk management mechanisms and between ex-ante and ex-post strategies. Traditional risk management covers actions taken both before (ex-ante) and after (ex-post) the risky event occurs (Siegel and Alwang, 1999). Ex-ante informal strategies are characterized by diversification of income sources and choice of agricultural production strategy. Mitigation, coping and transfer are the major strategies in agricultural risk management. Detailed description of these risk management strategies are:

***Mitigation:*** It is the act of reduction of the severity of adverse impacts of hazards and related disasters. Crop and livestock diversification, adoption of better agronomic practices, soil drainage, irrigation, use of resistant varieties, improved early warning systems and crop calendars etc are some of the risk mitigation options.

***Coping:*** It refers to the improvement of resilience to withstand and manage risk events, through ex-ante (before the risk event occurs) preparation and making use of informal and formal mechanisms in order to sustain production and livelihoods after the risk event. Government assistance to farmers and debt restructuring etc are some of the coping measures.

***Transfer:*** It refers to the transfer of potential financial consequences of some risk from one particular party to another willing party, at some cost. Insurance is the best-known form of risk transfer.

## Evolution of Agriculture Insurance in India

In India the crop insurance program as a pilot started during 1972 on H-4 cotton in Gujarat and was extended to few other crops and states later. Pilot Crop Insurance Scheme (PCIS) was launched by the Government of India on 'area approach' in 13 states of the country in 1979-80 and continued till 1984. Comprehensive Crop Insurance Scheme (CCIS) was in operation from 1985-1999 and was implemented on "Homogeneous area approach" in 16 states and 2 UTs of the country. In 1999 CCIS was replaced with a broad based scheme called National Agriculture Insurance Scheme (NAIS). The NAIS is presently administrated by Agriculture Insurance Company of India Limited, which provides coverage to approximately 35 different types of crops during *Kharif* and *Rabi* seasons. The government announced a pilot on improved version named Modified NAIS (MNAIS) w. e. f. *Rabi* season 2010-11 for experimentation in 50 districts. The new version has, to a large extent, taken care of the drawbacks in the existing NAIS. From November 2013, National Crop Insurance Programme (NCIP) / Rashtriya Fasal Bima Karyakram (RFBK) was formulated by merging Modified National Agriculture Insurance Scheme (MNAIS), Weather Based Crop Insurance Scheme (WBCIS) and Pilot Coconut Palm Insurance Scheme (CPIS).From the year 2016, a new crop insurance scheme named Pradhan Manthri Fasal Bima Yojana (PMFBY) was launched as a replacement of all the existing schemes *viz.*, NAIS, MNAAS, WBCIS etc.

## Weather Index Insurance (WII)

In WII, the indemnity is based on realization of a specific weather parameter measured over a pre-specified period of time at a particular weather station. The insurance was structured to protect against realization of either very high or very low indices that are expected to cause crop losses. For example, the insurance can be structured to protect against either too much or too little rainfall. An indemnity is paid whenever the realized value of the index exceeds a pre-specified threshold (when protecting against excess rainfall) or when the index is less than the threshold (when protecting against deficit rainfall). The indemnity is calculated based on a pre-agreed sum insured per unit of the index.

## Main features of Weather index-based insurance

The essential feature of WII is that the insurance contract responds to an objective parameter (e.g. rainfall or temperature) at a referred weather station during an agreed time period. The parameters of the contract are set so as to correlate, as accurately as possible, with the loss of yield of a specific crop suffered by the policyholder. All policyholders within a defined area receive payouts based on the same contract and measurement at the same weather station, eliminating the need for in-field assessment of yield loss.

In order for the underlying index to be a sound proxy for loss, it has to be based upon an objective measure (for example, rainfall, wind speed, temperature) that exhibits a strong correlation with the variable of interest (in this case, crop yield). Additionally, the weather variable that can form an index must satisfy the properties: i) Observable and easily measured, ii) Objective, iii) Transparent, iv) Independently verifiable, v) Reported in a timely manner, vi) Consistent over time and vii) Experienced over a wide area.

Important features of a WII contract are:

- A specific meteorological station is named as the reference weather station.
- A strike or trigger weather measurement is set (e.g. cumulative rainfall), at which the contract starts to pay out.
- A lump sum or an incremental payment is made (e.g. Rupees per mm of rainfall above or below the trigger).
- A limit or exit of the measured parameter is set (e.g. cumulative rainfall), at which a maximum payment is made.
- The period of insurance is stated in the contract and coincides with the crop growth period; it may be divided into phases (Maximum three), with each phase having its own triggers, increment and limit.

## Advantages and disadvantages of weather index based insurance

Though the development and application of weather index insurance (WII) is still in its early stages, the advantages and disadvantages of WII were well-documented (World Bank, 2005; USAID, 2006; IFAD and WFP 2010). Some of the relative merits and demerits of the WII are presented below (IFAD, 2010).

### i. Advantages of WII:

In comparison to the traditional damage based agricultural insurance, WII has advantages on the following aspects:

| | |
|---|---|
| • Transparency | • Addresses correlated risks |
| • No on-farm loss adjustment | • Low operational and transaction costs |
| • Lack of adverse selection | • Rapid payout |
| • Lack of moral hazard | |

Despite the merits of weather index based insurance mentioned above, acceptance WII by farmers is of slow due to the following disadvantages:

### ii. Disadvantages of WII:

| | |
|---|---|
| • Basis risk | • Temporal basis risk |
| • Spatial or geographical basis risk | • Product or crop specific basis risk |
| • Limited perils | • Requirement of Technical expertise |
| • Replication or Scalability | • Lack of weather data |

## Weather Index Insurance: Indian Experience

An impressive repository of historical weather data, high dependency of country's agricultural production on rains and huge pool of scientific resources place India in the forefront of piloting of weather index insurance.

## Pilot Weather Risk based Crop Insurance

The first pilot on weather index insurance in India and also in the developing world was carried out in 2003 by ICICI Lombard. This which was followed by pilots on weather risk index-based insurance by Agriculture Insurance Company of India (AIC) and IFFCO-Tokio, both during 2004. Building on the existing weather risk insurance products, the Government asked AIC in 2007 to design the Weather risk-Based Crop Insurance Scheme (WBCIS) as a pilot. An example of the product for multi-phase deficit rainfall and consecutive dry days is presented in Table 2.

**Table 2: Illustration of WBCIS in *Kharif* groundnut at Mahabubnagar, Telangana during 2004**

| Crop: Groundnut | | | Season: *Kharif* | | |
|---|---|---|---|---|---|
| | | | **PHASE-I** | **PHASE - II** | **PHASE – III** |
| 1 A. | Rainfall Volume | PERIOD | 21st June to $15^{th}$ July | $16^{th}$ July to $15^{th}$ Aug | $16^{th}$ Aug to $30^{th}$ Sept |
| | | TRIGGER I (<) | 80 mm | 160 mm | 80 mm |
| | | TRIGGER II (<) | 40 mm | 80 mm | 40 mm |
| | | EXIT | 20 | 30 | 20 |
| | | RATE I (Rs./mm) | 25 | 25 | 25 |
| | | RATE II (Rs./ mm) | 75 | 60 | 75 |
| | | Max. Payout (Rs.) | 2500 | 5000 | 2500 |
| | | **TOTAL PAYOUT (Rs.)** | **10000** | | |
| 1 B. | Rainfall Distribution (Consecutive Dry Days) | PERIOD | **1st July to 31st August** | | |
| | | TRIGGER DAYS (>=) | 20 | 25 | 30 |
| | | PAYOUT (Rs.) | 1500 | 3000 | 5000 |
| | | TOTAL PAYOUT (Rs.) | 5000 | | |
| | Rainfall of less than | 2.5 mm in a day shall not be considered as a rainy day; and multiple payouts considered | | | |
| | | Max. Payout (Rs.) | 15000 | | |

## Conclusions

Weather risk is assuming importance in agriculture due to climate change. Agriculture insurance has been identified as one of the risk management strategy for adapting to the climate change. In contrast to the traditional crop insurance scheme, weather index based insurance is gaining prominence because of its transparency, low operational costs and fast pay out mechanism. Yet, there are major constraints associated with weather index products that need to be successfully addressed. Foremost among the constraints is high basis risk. There is an urgent need to bring down basis risk arising from insufficient network and spread of weather stations besides improving relationships between the weather triggers and yield loss. Finally, there should be an in-depth research (on a continuous basis) of the associated weather risks for various crops grown in the country.

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# 4. Basics of Agrometeorology & Agro-climatic Characterization


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## Basics of Agrometeorology

Climate plays a fundamental role in agriculture. The production of food depends upon four factors namely plant and genetic material, weather, soil and water. Many other factors like management practices, size of the holding and enterprising nature of the farmer may also contribute to the success or failure of agricultural production. But weather plays a more decisive role and the farmer will have very little control on the weather. Weather will influence the agricultural production through its effects on soil chemistry and physics, plant growth and development, yield and yield components and in every phase of animal growth and production and through various atmospheric stresses (Bal and Minhas, 2017). So, the basic philosophy of agricultural meteorology is to make use of the science of meteorology in the interest of food production.

The agricultural production potential primarily depends upon the availability of moisture in the soil and the other important factor is the thermal regime. The growth and development of the crops is generally believed to take place when the mean daily temperatures are above 5°C. In tropical regions, the mean daily temperatures are much higher than 5°C throughout the year and therefore crops can be grown round the year, if water is available. In high altitude locations and in the interior regions beyond tropics, the mean daily temperatures will be less than 5°C during the winter season and therefore arable crop production is restricted to warm weather season only. Therefore, the agricultural climates all over the world are classified based on the two parameters i.e., the moisture regime and thermal regime.

Therefore, for efficient crop planning at agro-climatic zone level agroclimatic characterization is required. This characterization can be done using various agroclimatic indices. An agroclimatic index is a measure or indicator of an aspect of the climate that has specific agricultural significance. Agroclimatic or agrometeorological indices have great potential to quantify and communicate the impacts of climate change on agriculture. They can be used to describe the effects of climatic conditions on key agricultural aspects, including production, protection, fertilization, site selection, irrigation, etc. Therefore, agroclimatic indices can be very helpful for farmers in their decisions about crop management options and related farm technologies.

Generally, the crops can be considered to pass through important phases which can be distinguished from each other clearly under ideal conditions.

(i) During the first phase, the crop consists of individual plants which do not shade each other and the growth rate increases. A major part of the assimilates is invested in leaf growth and the increase in leaf area is proportional to the solar radiation intercepted. The plant weight increases at constant rate when water is not a limitation.

(ii) During the second phase, crop covers the soil completely and growth rate is constant if there is no limitation of water. A major part of the dry matter accumulation during the phase depends upon the growth rate and duration of the phase.

(iii) The crop is maturing and the growth rate is decreasing

The major environmental factors influencing phenological development are temperature and day length. The crops have a threshold temperature below which no growth takes place. By summing the daily temperatures above certain the threshold value (base temperature) during a particular phase, the number of thermal units (sometimes referred as degree days) required for completion of the phase can be obtained. The fraction of thermal units made available to the crop compared to the thermal units required for a particular phase will provide a numerical value of the development stage. Starting from the date of sowing, the first phase covers germination of seeds, emergence of seedlings and vegetative phase. The second phase covers fifty per cent flowering, grain formation and grain filling stages. The third phase covers physiological and harvest maturity stages.

## Agrometeorological Observatory and Weather Data Recording

Meteorological observations are taken regularly and simultaneously at standard hours of observations all over the world. However, agrometeorological observations are taken at 0700 and 1400 hrs LMT (Local Mean Time), when crop canopy level micro-climate is assumed to be the same throughout the country. Agromet observations are categorized in three types *viz.*, Principal, Ordinary and Auxiliary. A well exposed, bare level plot of 55 m (N-S) by 36 m (E-W), located more or less at the centre of the area, free from water logging and easily accessible even during the wettest weather, representative of the soil of the location is ideal for an observatory. The site should be well away from trees, high buildings, main irrigation channels, drainage etc. It is necessary to enclose the observatory with wire fencing for the safety of the meteorological instruments. The basic instruments installed in an observatory are Wind instruments (anemometer and wind vane), 2) Raingauge, 3) Thermometers (maximum, minimum, dry-bulb and we-bulb) 4) Barometer 5) Sun-shine recorder etc. The thermometers are kept in Stevenson's Screen made up of wood.

## Agro-climatic Characterization:

### Climatic classification

As the agricultural production potential of a region is mostly governed by two factors namely precipitation (P) and potential evapotranspiration (PET), the climates are generally classified using the concept of moisture index (MI) which is given by the formula

$$MI = \left(\frac{P-PET}{PET}\right) X\ 100$$

| Value of MI | Climate type |
|---|---|
| < -66.6 | Arid |
| -33.3 to -66.6 | Semi-arid |
| -66.6 to 99.9 | Sub-humid |
| ≥ 1.0 | Humid |

In tropical countries, where temperature is not a limitation for growing crops / vegetation round the year, the UNESCO classification suggests the relationship between the climate and water availability period as follows, with the assumption that water received through precipitation is not lost through run-off and deep drainage.

| Climate | Water availability period in days |
|---|---|
| Arid | < 73 days |
| Semi-arid | 74 to 182 days |
| Sub-humid | 183 to 364 days |
| Humid | 365 days |

Therefore, the cropping patterns under rainfed conditions in tropical regions can be related to the climatic type as follows:

| Climatic region | Cropping pattern under rainfed conditions |
|---|---|
| Arid | Grasses, shrubs, short duration pulse crops and pearl millet |
| Semi-arid | Short, medium and long duration crops, Inter cropping systems if the soils are deep with high water holding capacity |
| Sub-humid | Rainfed rice based cropping systems, horticultural crops |
| Humid | Rice based cropping systems, plantation crops |

Therefore, climate of the region plays a major role in the choice of crops and cropping systems under rainfed conditions in tropical regions depending upon the nature of the soil.

## Climatic Normals & Indices

Climatic normal are determined for a location by averaging the values of at least 30 years for different weather parameters.

**Growing Degree-day Concept:** GDD =∑ [(Tmax + Tmin)/2] – Tbase

Where, (Tmax + Tmin)/2 is the average daily temperature and Tbase is the minimum threshold temperature for a crop

**Photo thermal units (PTU):** PTU = Degree day (°C) * Day length (hours)

**Helio thermal units (HTU):** HTU = Degree day (°C) * Actual bright sunshine hours

**Thermal Interception Rate (TIR) =** TIR=PARI/n (Tm-Ta)

Where, PARI= Photosynthetically Active Radiation intercepted by the crop, n= No. of plants/$m^2$, Tm = Mean daily temp and Ta = base temp

**Photo-thermal Quotient (PTQ):** It is calculated daily during the crop growing period using the formula

If T < 4.5, PTQ/day = 0;If 4.5 < T < 10, PTQ/day = Solar Radiation * [(T – 4.5) / 5.5] /5.5; If T > 10, PTQ/day = Solar Radiation / (T - 4.5)

Where T is the daily mean temperature [(max + min) / 2] and PTQ is expressed asMJ/$m^2$/day/°C

**Temperature and Humidity index:** HTR was calculated as the ratio of daily average relative humidity and daily average temperature and SHTR was calculated as the ratio of daily afternoon relative humidity and MXT

**Aridity Index ($I_a$)** = [Water Deficit (WD) / Water Need (PET)] * 100

**Humidity Index ($I_h$)** = [Water Surplus (WS) / Water Need (PET)] * 100

**Moisture Index ($I_m$)** =$I_h$ - $I_a$= (P – PET) / PET

**Moisture Availability Index (MAI):** MAI = PD/PET

MAI is defined as the ratio of 75% rainfall Probability amount (PD) and PET

**Moisture Adequacy Index:** It is defined as the ratio of actual evapotranspiration and potential evapotranspiration (MAI = AET/PET) and is widely used in CWM.

## Length of Growing Period (LGP)

Considering the specific requirement of farmers in a domain, growing period has to be demarcated based on the climatological information and if any steps taken for rigorous introduction of high tech agriculture within growing period, it would bring reward of assured production. For assessment of climatic suitability of a particular crop in a region, length of Growing Period (LGP) is key parameter. According to FAO Agro-Ecological Zones Project length of growing period is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration. A period required to evapotranspire an assumed 100 mm of water from excess precipitation stored in the soil profile is sometimes added. This means that if a plant is grown in an identified LGP, the probability of getting soil moisture stress is negligible.

## Dry-spell & wet-spell/ heavy rainfall events

To achieve the highest yield potential and reduce the yield gap, the information on distribution of rainfall within the season is vital. The distribution of rainfall rather than deficiency in total seasonal rainfall can significantly influence crop growth and productivity (Monteith, 1991). A dry spell may be defined as an extended period of dry days, where a dry day is a day with precipitation less than a preselected threshold. The spatio-temporal analysis of dry and wet spells of rainfall is important for improving water management strategies and reducing socio-economic losses.

The information on duration of dry spells could be employed for deciding a particular crop or crop variety, and breed varieties of various crop durations for a specific location. Information on dry-spell lengths can also be used in deciding adaptation strategies *viz.*, supplementary irrigation and field operations in agriculture. Prior knowledge of dry spells can be applied to generate synthetic sequences of rainfall and estimation of the irrigation water demand. Comprehensive details about rainfall probability and distribution are essential for taking weather sensitive agricultural operations.

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# 5. Risk Management through Agromet Advisories


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Climate is a very important natural resource decides a crop of a location. Indian agriculture is prone to weather/climate related problems since ages despite the advancement in technology. Crop requires congenial weather conditions from sowing to harvest for its growth, attaining different stages from time to time, for functioning internal physiological processes. Meteorological events like onset of monsoon, rainfall distribution, dryspells & droughts, heavy rainfall, gusty winds, heat & cold waves, frost conditions, hail storms, flash floods and cyclones reduces the crop performance, damages the crop within no time and leave the farmer in a difficult situation. Poor farmers at the subsistence level have very little cash in their hand. Most of their input investments go for crop protection which they obtain through loans at high interest rates. When there is crop failure due to extreme variability in climate such as droughts etc. the poor farmers lose their entire investment and struggle under severe pressures.


Major risks in agriculture are categorized into production, financial and marketing. Under the production, weather plays a major role right from field preparation to procurement of seed, fertilizer, sowing and intercultural operations, management of pest disease infestation, fixing harvest time, storage of produce. Whereas under financial threat, basic risk is again with weather. One extreme weather event like hailstorm, flood, cyclone and drought may damage the crop and lead to loss of crop. This intern impacts the farmer with investment loss and debts. Finally, if a farmer could not find a good market and price, he will be at loss due to reduced income.

In India, major crops are grown during June to September under the summer monsoon rains which starts from the month of June. So, the onset of monsoon itself decides which crop and variety to be sown and what kind of field operations is required according to the distribution of monsoon rains. Forecasting of weather plays an important role here for taking any decision at field level. Normal agronomic advisories do not have the weather input before fixing any field operation. But Agromet advisory (AAS) is the value addition to advisory based on weather forecast.

The Agromet Advisory Services provide a very special kind of inputs to the farmers as advisories that can make a tremendous difference to the agriculture production by taking the advantage of benevolent weather and minimize the adverse impact of malevolent weather. Way back to1945, IMD started regular weather services for farmers in the form of a "Farmers' Weather Bulletin" and broadcasts through All India Radio in regional languages. In 1971, on the recommendation of the National Commission on Agriculture (NCA), it launched Agrometeorological Advisory Services (AAS), a comprehensive tool tailored to farmers' need. Then in 1975-1976, the U.S. National Aeronautics and Space Administration (NASA) conducted a Satellite Instructional & Television Experiment (SITE) with IMD and agricultural agencies that led to the production of crop specific weather-based agronomic advisories for different regions of the country. These integrated Agromet Advisory Services were further developed in 2007 and have steadily been improved by collaborating with ICAR and SAUs.

Now IMD started issuing several kinds of forecasts for the policy makers, farmers, general public and scientists and business purposes. The following are the variety of forecasts issued by IMD and their use in agriculture

- Short range forecast – valid for 24-48 hours- used for deciding the Application of irrigation water, fertilizers, harvesting etc.,
- Medium range forecast – valid for 3-10 days- Sowing, transplanting, irrigation, fertilizers, plant protection, measures, harvesting and threshing etc.
- Long range forecast - more than 30 days, month, season etc.- Crop planning, Selection of cultivar etc.
- Nowcasting is the forecast within 6 hours time- Used for thunder storms, heavy rains in a particular area, Sometimes hail prediction (half hour before only), wind prediction
- Extended Range Forecast for 15 days and above- Used for planning of farm operations

With the advancement in forecast technology, now India is capable of forecasting the weather from seasonal scale to Nowcasting with confidence at national level to block level. Whereas Value addition to these forecast for the benefit of farmers is done by All India Coordinated Research Project on Agrometeorology(AICRPAM) under Indian Council of Agricultural Research under Ministry of Agriculture and Farmers Welfare, Government of India, through its research partners in State Agricultural Universities in collaboration with farmers at field level. The combination of these value added forecasts and advisories are called 'Agromet Advisories' developed and disseminated to farmers using traditional 'Dandora' method to latest mobile apps and web based applications like 'mKisan'. This has a potential to change the face of India in terms of food security and poverty alleviation. Agro-meteorological service rendered by India Meteorological Department (IMD), Ministry of Earth Sciences is a step to contribute to weather information based crop/livestock management strategies and operations dedicated to enhancing crop production in a sustainable manner. These AAS are benefitting the farmer to take the farm level decisions and also helping the district level authorities to plan accordingly.

**Agromet advisories are farmers bulletins prepared with following information**

- Prevailing weather
- Soil and crop condition
- Weather prediction.
- Measures / practices / suggestions based on weather forecast

Agro-advisory bulletin consist of three parts:

1. Weather events occurred during past week and weather forecast for five days ahead. (RF, WS, WD, RH, max & min T)
2. It contains actual information on state and stage of crop growth, ongoing agricultural operations, disease and insect pest occurrence.
3. It provides value added information on various farm activities to be taken based on weather

IMD initiated district level agromet advisories with medium range weather forecasts on weekly basis and the crop information at district level will be collected by AFMUs and GKMS centers. By integrating this information Agrometeorologists and other SMSs discuss and devise Agromet advisories which are then disseminated to the farmers through different forms of ICTs. Further, feedback is collected from the farmers to evaluate the performance of the advisories provided. The lacunae will be identified for further improvement in agromet advisories.

## Micro level agromet advisories

District level Agromet advisories make a blanket recommendation of advisories which may not be viable for block level. So, looking into the exigency, AICRPAM developed a methodology for issuing the advisories at block level. The microlevel agromet advisories are prepared at block level. Agrometeorologist collects the block level forecasts and also appraises the current weather situation in the block to the subject matter specialists of the local KVK. There is a ‘Farm Information Facilitator’ (FIF) who is acting as the interface between the farmers and the SMSs at KVK, who collects the information on crop condition, farmers observations/ queries and passed on to the KVK SMSs. Then both the Agrometeorologist and SMSs discuss the situation and develops the Agromet Advisories and handed over to FIF for communicating to the Farmers of the village and disseminate the same using other ICTs to reach all the farmers in the villages of the block. Feedback will be collected for evaluation and improvement of the Agromet advisories at micro level.


## Dissemination mechanism

Information on weather needs to reach the farmer as soon as possible so that he can take suitable decision to manage his crop. The Information Communication Technology (ICT) in different ways enabled the dissemination of agromet advisories easy, multi lingual compatibility and timely.

### Issues

- Messages are too big and technical
- English is the main language used
- Messages are issued by Government as well as private operators and Farmer is confused
- Need to create awareness to the farmers on how to understand use the messages

# 6. Polymers for Improving Water and Fertilizer Use Efficiency in Different Crops Grown in Rainfed Areas

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The problem of inefficient use of rain & irrigation water by crops is most important in rainfed agriculture in semiarid and arid regions. Application of water-saving super absorbent polymers (SAP) in to the soil could be an effective way to increase both water and nutrient use efficiency in crops (Lentz *et al.* 1998). When polymers are incorporated with soil, it is presumed that they retain large quantities of water and nutrients, which are released as required by the plant. Thus, plant growth could be improved with limited water and nutrient supply (Gehring and Lewis, 1980).

Super absorbents were introduced to the markets in early 1960s, by the American company, Union Carbide (Dexter and Miyamoto, 1995). The product absorbed water thirty times as much as its weight and did not last long was unsuccessful in market (Joao *et al.* 2007). In fact materials having the capacity to absorb water 20 times more than their weights are considered as a super absorbent (Abedi-Koupal and Sohrab, 2004). But due to development of more cross linked polymers with high water holding capacity (400 times & in some cases even up to 2000 times of their weight) and comparatively low cost than earlier ones has rejuvenated interest on the use of polymers in agriculture.

## Types of polymers

Both water soluble and insoluble polymers have been marketed for agricultural use. Water-soluble polymers do not form gels and are used as soil conditioners. These include poly (ethylene glycol), poly (vinyl alcohol), polyacrylates and polyacrylamides. Water soluble polymers were developed primarily to aggregate and stabilize soils, combat erosion and improve percolation, and by doing so, improve crop yields on very droughty and structure less soils. Although some of these materials (polyacrylates and polyacrylamides) use the same chemical building blocks as the gel-forming polymers, soil conditioners possess what chemists refer to as linear chain molecular structure and do not form water-absorbing gels.

Insoluble water-absorbing polymers were first introduced for agricultural use in the late1970s and early 1980s. Depending on the type of polymer and the conditions during synthesis, water absorbing polymers have the ability to absorb up to 1,000 times (or more) of their weight in pure water and form gels. Because of their tremendous water-absorbing and gel-forming abilities, they are referred to as super absorbents or hydrogels. There are three main groups of hydrogels, (i) Starch-graft co-polymers, (ii) Polyacrylates, (iii) Acrylamide-acrylate co-polymers.

## Effects of polymer application on soil and crop

### (i) Effect of application of polymers on soil moisture storage and water use efficiency:

When polymers are incorporated into a soil or soilless medium, they retain large quantities of water and nutrients. These stored water and nutrients are released as required by the plant. Thus, plant growth could be improved, and/or water supplies conserved. It has been reported that a 171% to 402% increase in the water retention capacity is recorded when polymers were incorporated in coarse sand (Ekabafe *et al.* 2011). It has been reported that increased water retention capacity attributed to polymer addition significantly reduced irrigation frequency (Flannery and Busscher, 1982) and the total amount of irrigation water required. Regarding the available moisture, the best results were obtained with application of PR3005A polymer in levels of 4 and 8 g/kg in loamy soils. The moisture amount in this situation was increased by 2 to 4 times respectively (Ghaiour, 2000). Sivapalan (2006) stated that the retained water in sandy soil was equal to 23 and 95% with application of polymer at 0.03 and 0.07% of its weight, respectively. Johnson (1984) estimated that applying super absorbent to sandy soils cause an increment in water holding capacity from 171 to 204%.

### (ii) Effect on Soil and its Erosion:

Super absorbent polymers affect water penetration rate, density, structure, compactness, texture and crust hardiness of soil, aggregate anchorage (Helalia and Letey, 1989) and evaporation (Tayel and El-Hady, 1981), soil infiltration and aeration, size and number of aggregates, soil's water tension, available water, soil crispiness[18] and finally cause better water management practices in soil.

Non-cross-linked anionic polyacrylamides (PAM, containing <0.05% AM) having very high molecular weight (12-15x$10^6$ g $mol^{-1}$), have also been used to reduce irrigation-induced erosion and enhance infiltration. Its soil stabilizing and flocculating properties improve runoff water quality by reducing sediments, N-dissolved reactive phosphorus (DRP), chemical oxygen demand (COD), pesticides, weed seeds, and microorganisms in runoff.

### (iv) Effect on Crop growth:

Super absorbent polymers cause improvement in plant growth by increasing water holding capacity in soils (Boatright *et al.* 1997) and delaying the duration to wilting point in drought stress (Gehring and Lewis, 1980). Water conservation by gel creates a buffered environment being effectiveness in short term drought tension and losses reduction in establishment phase in some plant species. Totally, proficiency in water consumption and dry matter production are positive plant reactions to super absorbent application (Woodhouse and Johnson, 1991).

Poly (ethylene oxide) hydrogel, polyacrylamide hydrogel and cross-linked poly (ethylene oxide)-co-polyurethane hydrogel were attempted to alleviate the plant damage that resulted from salt-induced and water deficient stress (Shi *et al.* 2010).

## Factors affecting super absorbent polymer performance

With hydrogel use it was observed that increased water-holding capacity, reduced irrigation frequency, greater water use efficiency, enhanced infiltration rates, reduced compaction tendency and increased plant performance. Perhaps a critical assessment of the variables that affect hydrogel performance will help explain why. These variables include polymer type, rate and grind size, method of application, salinity of the soil solution, effects of specific ions, soil texture, temperature, intended use etc.

### (i) Type of polymer

As sated earlier, there are three main groups of hydrogels. They differ widely in their total absorbency, time needed to hydrate, structural integrity and longevity in the soil. Starch-graft co-polymers may take up to a few hours to hydrate completely, however, they do not possess the gel strength or longevity that cross linked acrylamide-acrylate co-polymers do (Grula and Huang, 1982). Activity of starch-graft co-polymers is usually limited to a single season, whereas, the cross linked acrylamide-acrylate co-polymers remain active for five to seven years or longer.

### (ii) Particle size of polymer

Water absorbing polymers are available in various particle sizes, from powders to coarse granules greater than 2 mm in diameter. The effect of powders versus coarse granules on root zone characteristics such as oxygen diffusion rate and water absorption may be very different. If a continuous layer of powder is applied, gas exchange to the roots may be severely reduced. Research that compares powders to fine and coarse-grade granules for their ability to affect gaseous exchange is badly needed.

### (iii) Soil texture

Potential benefit of polymers on water storage also depends on the soil texture. The amount of water that may be retained by incorporating a polymer would be greater in coarse textured soils than in fine textured soils. The bulk density of loamy and sandy soils reduced with polyacrylamide (PAM) addition compared to the control while there was a small increase in bulk density of clayey soil. Conversely, porosity increased with increasing PAM rates for clay loam and sandy soils. However, macro pore size increased in clay soil while it decreased in clay loam and sandy loam soils (Uz *et al.* 2008). Available water contents of loamy and clay soils showed highly significant increase (108% and 105%, respectively) with the highest 0.67% PAM rate applied due to increase in water content at Field Capacity (FC) and decrease in water content at Wilting Point (WP). Meanwhile, plant available water content of sandy soil increased by 55% since water content at WP increased.

### (iv) Salt concentration in water and soil solution

Johnson (1984) reported that water holding properties of polymers significantly affected by nature and dissolved salts concentration in water of irrigation. Saline water reduces absorption and conservation of water. Akhtar *et al.* (2004) evaluated effect of water kind on amount and rate of absorption and reported that the maximum time for absorption with distilled water, tap water and saline water were 7, 4 and 12 hr, respectively and the amount of absorption in 1 hr was measured as 505, 212 and 140 g/g, respectively. Increase in water salinity in amount of more than 2.5 dS $m^{-1}$ caused reduction in polymer effectiveness in loamy sandy soils and the plants irrigating with 5 dS $m^{-1}$ used 42% more than that of with 1.6 d S $m^{-1}$ (Bhat *et al.* 2009). Among various $NO_3^-$ containing salts, hydration of a cross linked polyacrylamide was inhibited most by the presence of $Al^{3+}$. Similarly, divalent cations ($Ca^{2+}$ and $Mg^{2+}$) had a greater inhibitory effect on polymer expansion than did monovalent cations ($NH_4^+$, $Na^+$, and $K^+$). The effect of $NH_4^+$ based salts on polymer expansion (where the cation remained constant but the anion changed) was much less, indicating that the source of cation has a much greater effect on polymer hydration than does the source of anion.

### (v) Rate of application of polymers

Polyacrylamide (PAM) rates applied to soil may need to be adjusted based on soil properties, slope, and type of erosion targeted. PAM with newer longer-chain polymers is more effective even in lower rates (Wallace and Wallace, 1986). Application of 20 kg $ha^{-1}$ PAM prior to sprinkler irrigation increased infiltration rates and reduced runoff and erosion (Stern *et al.* 1992).

Overusing of hydrogels causes reverse results, because it reduces soil air followed by filling vacant spaces and gel swelling. There are many reports of no effect or low effect of gels in overused application of them in soil in growth indices of plants. The main reason as mentioned is due to occupation of many vacant spaces of soil resulting in sever soil ventilation (Abedi-Koupai and Mesforoush, 2009). Sarvas *et al.* (2007) in an experiment on *Pinus sylvestris* L. seedlings observed that by over using of super absorbent in soil; plants were more likely to exposure to Fusarium diseases and mostly perished. They suggested that some investigation needs to be carried out to find out the most suitable amount of hydrogel in different situation and plant species.

Application of 28 kg water absorption polymer (Bhagiratha) per hectare along with recommended rates of fertilizers to pigeon pea maintained higher soil moisture level in sandy loam soil at different growth stages of crop and produced higher seed yield and nitrogen uptake by 12 and 10%, respectively as compared to control (only fertilizers) (Mondal, 2011). Use of 0.75% (w/w) water soluble polymers with 50% Attainable Moisture Depletion (AMD) to tomato in sandy loam soil produced the highest yield (59.6 t/ha) and maximum water use efficiency (153.6 kg/$m^3$) as compared to other levels of polymer application (0, 0.25, 1.25 and 1.75%) (Lakshmi, 2011). Application of carboxymethyl cellulose at 2% and 4% rate with 5 tonne compost/ha resulted in increase of maize yield by 25 and 34%, respectively over the untreated sandy soil. The combined effect of both soil conditioners on water and nutrient use efficiency were better than that of their sole application.

### (vi) Method of application of polymers

The performance of the gel on plant growth depends on the method of application as well. It was shown that spraying the hydrogels as dry granules or mixing them with the entire root zone is not effective (Flannery and Busscher, 1982). Better results seemed to be obtained when the hydrogels are layered, preferably a few inches below soil surface. However, generalizations should be avoided when interpreting results as a number of factors such as types of gel, particle size, rate of application, and type of plant has to be taken into consideration.

### (vii) Biodegradation of polymer

The persistence of a particular polymer in the soil may affect its usefulness as a device to delay the release of water and nutrients. In general, naturally occurring polymers are readily degraded by soil microorganisms, while synthetic polymers are more resistant to biological breakdown. Many of the natural polymers contain chemical bonds that may be broken through common enzymatic hydrolysis in soils. The synthetic polymers typically demonstrate much greater resistance to biological attack, since soil microbes have not yet developed the polymer-specific enzymes required for rapid decomposition.

### (viii) Temperature

In soil, polyarylamide polymers degrade at rates of at least 10% per year as a result of physical, chemical, biological and photochemical processes (Tolstikh *et al.* 1992). Intense UV radiation in the open is known to increase the breakdown rates. Bhat *et al.* (2009) investigated the effects of high temperatures on the performance of PAM polymers using ornamental plant (*Concarpus lancifolius*) in sandy soil under three temperature regimes, *viz.*, Variable Ambient Temperature (VAT), Environment Controlled Greenhouse (GH) and indoor temperature regimes (LAB). The plants grown at 0.4% PAM required 33.8, 38.1 and 30.7% less water than control (no PAM) in VAT, GH, LAB conditions, respectively. The reduced effectiveness of polymers in the VAT regime to a large extent may be related to their degradation due to high temperature and light intensity (Tolstikh, 1992).

## Conclusions and Future Directions

Determination of amount of gel for the best performance is influenced by many factors including, climate, substance type (chemical composition and forming method), soil type

(Texture, structure and chemical properties), plant species etc. Thus, it is recommended that studies have to be carried out to determine the most suitable amount of hydrogel for each species of plant, climate and substance, individually. In India, very little research work has been done on polymers comparatively. The rate of application of polymers recommended by different polymer suppliers varies from 2.5 kg/ha to 60 kg/ha depending upon type of polymer and crop. Another issue is the longevity of polymers in soils, some polymers are being recommended every year and some other are recommended with 3-5 years of frequency due to their longer longevity in soils. Therefore, systematic field studies under arid and semi-arid conditions of India are needed to develop appropriate rate, frequency and method of application of different polymers to various crops and to assess economics of use of different polymers. It is also essential to determine the duration of effectiveness of the polymers in the soil for economizing their use in agriculture.

There is a need to assess the effect of application of polymers on fertilizer efficiency along with water use efficiency in various crops under variety of soil conditions and different nutrient management systems (such as fertilizers alone, integration of fertilizers and organic manures and only organic manure application). The effect of different methods of application of polymers such as seed treatment, soil application (Broad casting, dibbling, deep placement, row application, wet patch application, etc), root dipping needs to be evaluated on establishment of crops and their growth in dryland areas which is very critical for farmers livelihood.

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# 7. Role of Conservation Agriculture in Improving Soil Health and Adaptation and Mitigation of Climate Change

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The World Bank Group (2019) has estimated that the world population may reach nearly to 10 billion people by the year 2050. In order to provide them food, clothes, house, clean water and energy for their homes and vehicles, is a challenging task. Meeting these needs will require healthy and productive land which is a foundation for all life-sustaining processes on the planet. Further, they have reported that globally, about a quarter of the Earth's land surface, roughly 2 billion hectares, has already been degraded and about 1.5 billion people are affected by land degradation, especially rural communities, smallholder farmers, and the very poor. The vast majority of people who depend on drylands live in developing countries, where women and children are most vulnerable to the impacts of land degradation and drought. Land degradation is caused by multiple forces, including extreme weather conditions particularly drought, and human activities that pollute or degrade the quality of soils and land utility negatively affecting food production, livelihoods, and the production and provision of other ecosystem goods and services.

The process of land degradation has accelerated during the 20th century due to increasing and combined pressures of agricultural and livestock production (over-cultivation, overgrazing, forest conversion), urbanization, felling of the forests or deforestation, and extreme weather events such as droughts and intrusion of sea water which salinate land. Another form of land degradation is desertification, which is a form of land degradation, by which fertile land becomes desert. Land degradation and desertification can affect human health through complex pathways. As land is degraded and in some places deserts expand, food production declines, water bodies dry up and populations are pressured to move to more hospitable areas. Consequently land degradation and desertification affects human nutrition and health.

Globally, it is expected that climate change may result in more frequency of droughts, floods, hailstorms, cyclones, extreme temperatures and extreme rainfall events. These extremes will further aggravate the processes of land degradation and deterioration of soil health and consequently the decline in crop productivity and environmental quality. Therefore, it is inevitable to look for the revised soil and crop management practices such as conservation agriculture comprising of reduced or minimum tillage, crop residue recycling, appropriate crop rotations by including legume crops and other cover crops. These practices will not only work as adaptation measures of climate change but will also act as climate change mitigation strategies in long run.

## Indian Scenario - Land degradation and its Predominant Causes

In India , out of its 329 m ha of total geographical area of the country , about 120.7 m ha of is under the severe grip of degradation, of which 73.3 m ha is affected by water erosion, 12.4 m ha by wind erosion, 6.73 m ha by salinity and alkalinity and 25 m ha by soil acidity. Out of an estimated net cultivated area of about 142.2 m ha, only about 73 m ha is area is rainfed and is dependent on Rain God. The irrigated area produces about 56% of total food requirement of India. The first predominant cause of soil degradation in rainfed regions undoubtedly is the water erosion. The process of erosion sweeps away the topsoil along with organic matter and exposes the subsurface horizons. The second major indirect cause of degradation is loss of organic matter by virtue of temperature mediated fast decomposition of organic matter and robbing away of its fertility. Above all, the several other farming practices such as reckless tillage methods, harvest of every small component of biological produce and virtually no return of any plant residue back to the soil, burning of the existing residue in the field itself for the preparation of clean seed bed, open grazing etc aggravate the process of soil degradation. Consequent to land degradation and deterioration of soil health, the productivity of crops, water use efficiency and water productivity have gone down in rainfed agriculture which is a matter of great concern.

## Likely impact of Climate Change on Soil Health

1. Erosion with excessive torrential rains
2. Loss of organic matter, clay and nutrients from top soil layers
3. Leaching of nutrients and pollutants to ground water
4. Acceleration in decomposition of organic matter and loss of SOC
5. Breakage of soil aggregates with rainfall and loss of entrapped organic carbon
6. Carbon emissions with high temperature owing to higher microbial activity and decomposition
7. Higher root respiration
8. Rapid rate of mineralization, nutrient losses through volatilization and leaching
9. Exposure of buried organic carbon from soil due to temperature rises in permafrost soils
10. Intrusion of sea water into main land due to rise in water table leading to salinity and salt accumulation.
11. Higher rate of GHG,s emissions

## Conservation agriculture and its components

Conservation agriculture is a practice that reduces soil erosion, sustains soil fertility, improves water management and reduces production costs, making inputs and services affordable to small-scale farmers. Conservation agriculture is defined as a set of practices aimed at achieving the following three principles simultaneously: i) maintaining adequate soil cover, ii) disturbing the soil minimally, and iii) ensuring crop rotation and intercropping. Conservation agriculture as defined by Food and Agricultural Organizations (FAO) of the United Nations is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. It is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt the biological processes (Philip *et al.,* 2007). Conservation agriculture, in broader sense includes all those practices of agriculture, which help in conserving the land and environment while achieving desirably sustainable yield levels. Tillage is one of the important pillars of conservation agriculture which disrupts inter dependent natural cycles of water, carbon and nitrogen. Conservation tillage is a generic term encompassing many different soil management practices. It is generally defined as ‘any tillage system that reduces loss of soil or water relative to conventional tillage; mostly a form of non-inversion tillage allows protective amount of residue mulch on the surface (Mannering and Fenster, 1983).

Lal (1989) reported that the tillage system can be labeled as conservation tillage if it i) allows crop residues as surface mulch, ii) is effective in conserving soil and water, iii) maintains good soil structure and organic matter contents, iv) maintains desirably high and economic level of productivity, v) cuts short the need for chemical amendments and pesticides, vi) preserves ecological stability and vii) minimizes the pollution of natural waters and environments. In order to ensure the above criteria in agriculture, there is a need to follow a range of cultural practices such as i) using crop residue as mulch, ii) adoption of non-inversions or no-tillage systems, iii) promotion of crop rotations by including cover crops, buffer strips, agro-forestry, etc., iv) enhancement of infiltration capacity of soil through rotation with deep rooted perennials and modification of the root zone; v) enhancement in surface roughness of soil without jumping into fine tilth, vi) improvement in biological activity of soil fauna through soil surface management and vii) reducing cropping intensity to conserve soil and water resources and building up of soil fertility. However, some of the discouraging and undesirable effects of conservation tillage have been reported as: (1) Increase in use of herbicides and consequently increased cost, (2) problems and difficulties in controlling of some of the infested weeds, (3) difficulty in managing poorly drained soils, (3) slower warming of temperate soils due to surface residue layer during winter and springs which delays germination and early growth. However, in tropics this negative aspect can become an asset in helping in maintaining relatively lower temperature and thereby enhancing germination. It also helps in preserving soil and water resources.

## Why conservation agriculture is the need of the hour in rainfed areas

As the soil quality degradation is more prominent in rainfed agro-ecoregions because of natural and human induced crop husbandry practices, which call for the adherence to the conservation agriculture management as top priority. Conservation agriculture has the main aim of protecting the soil from erosion and maintaining, restoring and improving soil organic carbon status in the various production systems, hence more suited and required in rainfed agriculture. Predominantly, this goal can be achieved through minimizing the soil tillage, inclusion of crop rotation or cover crops (mostly legumes) and maintaining continuous residue cover on soil surface.

Tillage, which is one of the predominant pillars of conservation agriculture, disrupts the inter-dependent natural cycles of water carbon and nitrogen. Tillage unlocks the potential microbial activity by creating more reactive surface area for gas exchange on soil aggregates that are exposed to higher ambient oxygen concentration (21%). Tillage also breaks the aggregate to expose fresh surfaces for enhanced gas exchange and perhaps, may lead to more carbon loss from the interior that may have higher carbon-dioxide concentration. Thus, an intensive tillage creates negative conditions for carbon sequestration and microbial activity.

## Role of Conservation Agriculture in reducing the adverse effect of climate change

Conservation tillage and residue management helps in the following ways in influencing some of the soil properties and mitigating the adverse effects of climate change.

- **Soil Temperature**: Surface residues significantly affect soil temperature by balancing radiant energy and insulation action. Radiant energy is balanced by reflection, heating of soil and air and evaporation of soil water. Reflection is more from bright residue.
- **Soil aggregation:** It refers to binding together of soil particles into secondary units. Water stable aggregates help in maintaining good infiltration rate, good structure, protection from wind and water erosion. Aggregates binding substances are mineral substances and organic substances. Organic substances are derived from fungi, bacteria, actinomycetes, earthworms and other forms through their feeding and other actions. Plants themselves may directly affect aggregation through exudates from roots, leaves and stems, leachates from weathering and decaying plant materials, canopies and surface residues that protect aggregates against breakdown with raindrop impact, abrasion by wind borne soil and dispersion by flowing water and root action. Aggregates with. 0.84 mm in diameter is non-erodable by wind and water action. Well-aggregated soil has greater water entry at the surface, better aeration, and more water-holding capacity than poorly aggregated soil.

- Aggregation is closely associated with biological activity and the level of organic matter in the soil. The gluey substances that bind components into aggregates are created largely by the various living organisms present in healthy soil. Therefore, aggregation is increased by practices that favor soil biota. Because the binding substances are themselves susceptible to microbial degradation, organic matter needs to be replenished to maintain aggregation. To conserve aggregates once they are formed, minimize the factors that degrade and destroy them.

- Well-aggregated soil also resists surface crusting. The impact of raindrops causes crusting on poorly aggregated soil by disbursing clay particles on the soil surface, clogging the pores immediately beneath, sealing them as the soil dries. Subsequent rainfall is much more likely to run off than to flow into the soil. In contrast, a well-aggregated soil resists crusting because the water-stable aggregates are less likely to break apart when a raindrop hits them. Any management practice that protects the soil from raindrop impact will decrease crusting and increase water flow into the soil. Mulches and cover crops serve this purpose well, as do no-till practices which allow the accumulation of surface residue.

- **Soil density and porosity:** Soil bulk density and porosity are inversely related. Tillage layer density is lower in ploughed than unploughed (area in grass, low tillage area etc). When residues are involved, tilled soils will reflect lower density. Mechanization with heavy machinery results in soil compaction, which is undesirable and is associated with increased bulk density and decreased porosity. Natural compaction occurs in soils, which are low in organic matter and requires loosening. But, practicing conservation tillage to offset the compaction will be effective only when there is adequate residue, while intensive tillage may adversely influence the soil fauna, which indirectly influence the soil bulk density and porosity.

- **Effects on other physical properties:** Tillage also influences crusting, hydraulic conductivity and water storage capacity. It has been understood that the textural influences and changes in proportion of sand, silt and clay occur due to inversion and mixing caused by different tillage instruments, tillage depth, mode of operation and effect of soil erosion. Soil crusting which severely affects germination and emergence of seedling is caused due to aggregate dispersion and soil particles resorting and rearrangement during rainstorm followed by drying. Conservation tillage and surface residue help in protecting the dispersion of soil aggregates and helps in increasing saturated hydraulic conductivity. Increased HC in conjunction with increased infiltration resulting from conservation tillage allows soil profile to be more readily filled with water. Further, less evaporation is also supported by conservation tillage, and profile can retain more water.

- **Effect on soil organic matter and soil fertility:** Conservation agricultural practices help in improving soil organic matter by way of i) regular addition of organic wastes and residues, use of green manures, legumes in the rotation, reduced tillage, use of fertilizers, and supplemental irrigation ii) drilling the seed without disturbance to soil and adding fertilizer through drill following chemical weed control and iii) maintaining surface residue, practicing reduced tillage, recycling of residues, inclusion of legumes in crop rotation. These practices provide great opportunity in maintaining and restoring soil quality in terms of SOM and N in SAT regions. It is absolutely necessary to spare some crop residue for soil application, which will help in improving soil tilth, fertility and productivity.

Some research experiences showing the effect of conservation management practices on soil quality improvement

There are several reports on the influence of conservation agricultural management practices comprising of tillage, residue recycling, application of organic manures, green manuring and integrated use of organic and inorganic sources of nutrients, soil water conservation treatments, integrated pest management, organic farming, etc., on soil quality. Improved soil quality parameters create additional muscle power to soil to combat the ill effects of climate change. Some of the results pertaining to the effect of conservation agricultural practices on soil quality are given below:

➢ The studies conducted over a 9 year period in Alfisols at Bangalore with finger millet, revealed that the yields were similar with optimum N, P, K application and with 50% NPK applied through combined use of fertilizers + FYM applied @ 10 t $ha^{-1}$. Application of vermicompost in combination with inorganic fertilizer in 1:1 ratio in terms of N equivalence was found very effective in case of sunflower grown in Alfisol at Hyderabad (Neelaveni, 1998). Combined use of crop residues and inorganic fertilizer showed better performance than sole application of residue.

➢ Use of crop residue in soil poor in nitrogen (Bangalore) showed significant improvement in the fertility status and soil physical properties. Continuous addition of crop residues for five years enhanced maize grain yield by 25%. Organic matter status improved from 0.5% in the control plots to 0.9% in plots treated with maize residue at 4 t $ha^{-1}$ $year^{-1}$. In Alfisols at Hyderabad, use of crop residues in pearl millet and cowpea not only enhanced the yields but also made appreciable improvements in stability of soil structure, soil aggregates and hydraulic conductivity.

➢ Capitalisation of legume effect is one of the important strategies of tapping additional nitrogen through biological N fixation. There are many reports on this aspect (Singh and Das, 1984; Sharma and Das, 1992). The beneficial effect of preceding crops on the succeeding non-legume crops has been studied at many locations. When maize was grown after groundnut, a residual effect of equivalent to 15 kg N $ha^{-1}$ was observed at ICRISAT (Reddy *et al.* 1982). Sole cowpea has been reported to exhibit a residual effect of the magnitude of 25-50 kg N $ha^{-1}$ (Reddy *et al.* 1982).

- Based on a five year rotation of castor with sorghum + pigeon pea and green gram + pigeon pea in an Alfisol of Hyderabad, it was observed that green gram + pigeon pea intercrop (4:1) can leave a net positive balance of 97 kg $ha^{-1}$ total N in soil (Das *et al.* 1990).

- Results of a long-term study conducted on soil quality improvement revealed that the application of gliricidia loppings proved superior to sorghum stover and no residue treatments in maintaining higher soil quality index (SQI) values. Further, increasing N levels also helped in maintaining higher SQI. Among the 24 treatments, the highest SQI was obtained in conventional tillage (CT) + gliricidia loppings (GL) + 90 kg N $ha^{-1}$ ($CTGLN_{90}$) (1.27) followed by $CTGLN_{60}$ (1.19) and minimum tillage (MT) + sorghum stover (SS) + 90 kg N $ha^{-1}$ ($MTSSN_{90}$) (1.18), while the lowest was under minimum tillage + no residue (NR) + 30 kg N $ha^{-1}$ ($MTNRN_{30}$) (0.90) followed by $MTNRN_0$ (0.94), indicating relatively less aggradative effects. The application of 90 kg N $ha^{-1}$ under minimum tillage even without applying any residue ($MTNRN_{90}$) proved quite effective in maintaining soil quality index as high as 1.10. The key indicators, which contributed considerably towards SQI were, available N, K, S, microbial biomass carbon (MBC) and hydraulic conductivity (HC). Among the various treatments, $CTGLN_{90}$ not only had the highest SQI, but was most promising from the viewpoint of sustainability, maintaining higher average yield levels under sorghum-castor rotation. From the view point of SYI, CT approach remained superior to MT. To maintain yield as well as soil quality in Alfisols, primary tillage along with organic residue and nitrogen application are needed (Sharma *et al,* 2005).

- Another long-term experiment was conducted with two tillage (conventional (CT) and reduced (RT)) and five INM treatments (control, 40 kg N through urea, 4 t compost + 20 kg N, 2 t Gliricidia loppings + 20 kg N and 4 t compost + 2 t Gliricidia loppings) using sorghum and green gram as test crops. Tillage did not influence the soil quality index (SQI), while the conjunctive nutrient use treatments had a significant effect. The conjunctive nutrient use treatments aggraded the soil quality by 24.2 to 27.2%, while the sole inorganic treatment could aggrade only to the extent of 18.2% over the control. Statistically, the overall superiority of the treatments in aggrading the soil quality was: 4 Mg compost + 2 Mg gliricidia loppings (T5) > 2 Mg Gliricidia loppings + 20 kg N through urea (T4) = 4 Mg compost + 20 kg N through urea (T3) > 40 kg N through urea (T2). The extent of per cent contribution of the key indicators towards soil quality index (SQI) was: microbial biomass carbon (MBC) (28.5%), available nitrogen (28.6%), DTPA- Zn (25.3%), DTPA- Cu (8.6%), hydraulic conductivity (HC) (6.1%) and mean weight diameter (MWD) (2.9%) (Sharma *et al.,* 2008).

- Based on the network tillage experiment being carried out since 1999 at various centers of All India Coordinated Research Project on Dryland Agriculture (AICRPDA), it was observed that in arid (< 500 mm rainfall) region, low tillage was almost comparable to conventional tillage and the weed management was not so difficult, whereas, in semi arid (500 – 1000 mm) region, conventional tillage was found superior. It is a well-established fact that infiltration of rainfall depends on soil loosening and its receptiveness and thus requires more surface disturbance. Success of crops depends on rainfall infiltration and soil moisture holding in the profile.
- For improving the carbon content in soil, apart from crop residues, the agro-forestry also becomes important. However, nothing comes free. The agro-forestry system comprising of perennial components depends on the sub-soil components.

## How to promote conservation agriculture farming

**The following steps are needed to promote conservation farming in the future:**

1) There is a need to create awareness among the farmers about the importance of soil resources, organic matter build up in soil. Traditional practices such as burning of residues, clean cultivation, intensive tillage and pulverization of soil up to finest tilth need to be discouraged.
2) Systems approach is essential for fitting conservation tillage in modern agriculture. In order to follow the principle of "grain is to man and a residue is to soil", farming systems approach introducing alternative fodder crops is essential. Agro-forestry systems with special emphasis on silvi-pastures systems need to be introduced. Unproductive livestock herds needs to be discouraged
3) For the adoption of conservation tillage, it is essential that complete package of practices may be identified based on intensive research for each agro ecological region.
4) The increased use of herbicides has become inevitable for adopting conservation tillage/ conservation farming practices. The countries that use relatively higher amount of herbicides are already facing problem of non-point source pollution and environmental hazard. In order to reduce the herbicidal demand, there are scopes to study the allelopathic effects of cover crops and intercultural and biological method of weed control. In other words, due concentration is needed to do research on regenerative cropping systems to reduce dependence on inorganic chemicals.
5) Low tillage, crop rotation, cover crops, maintenance of residues on the surface, control of weeds through herbicides, are the key components of conservation farming. Therefore, it is essential that these themes must be studied in depth under diverse soil and climatic conditions across the country on long-term basis.

6) The other objective of conservation farming is to minimize the inputs originating from non-renewable energy sources. Eg. Fertilizers and pesticides. Hence, research focus is required on enhancing fertilizer use efficiency and reduction in use of pesticides. This aspect can be strengthened by following integrated nutrient management and integrated pest management approach.

7) The past research experiences of conservation tillage reveal that the major toll of yield is taken by poor germination and poor crop stand because of poor microclimatic environment and hard setting tendencies of soil, excessive weed growth and less infiltration of water to the crop root zone. Therefore, the important aspects which need concentrated research focus include appropriate time of sowing, suitable seed rate, depth of seed placement and soil contact, row orientation, etc. Suitable cultivars having responsiveness to inputs also become important component of conservation farming.

8) The issues related to development of eco-friendly practices for tillage and residue recycling- appropriately for specific combination of soil-agro climatic cropping system- to alleviate physical constraints with higher water and nutrient use efficiency need to be addressed.

9) Inter-disciplinary research efforts are required to develop appropriate implements for seeding in zero tillage, residue incorporation and inter-cultural operations.

## Conclusion

Based on the foregoing discussion, it can be concluded that conservational agriculture practices are panacea to address many issues of agriculture amidst likely climate change. In nutshell, it can be said that CA can act as a strong adaptation strategy to manage extreme climatic events such as wind and water erosion, because in this system soil is protected by crop residues, and not frequently loosened by tillage. Moreover, improved soil aggregation makes it more resistant towards wind and water erosion. Improved soil moisture status and decreased evaporation loss might mitigate drought situations. These practices also help in regulating the extreme temperature flow (heat/frost) in soil by covering the soil surface. Another important beneficial aspect of conservation agriculture is that it can help in improving water infiltration into soil and enhances groundwater recharge with rain water, consequently reducing flood and erosion problems during heavy rainfall. Besides these, CA plays important role in improving soil organic carbon and soil fertility. Apart from adaptation strategy, CA can be a successful mitigation strategy to climate change by way of sequestering more carbon in the soil and reducing the $CO_2$ fluxes to atmosphere. According to Baker *et al.* 2007 adoption of conservation tillage in all the crop land could potentially sequester 25 Gt C over the next 50 years, which is equivalent to 1833 Mt $CO_2$- eq year$^{-1}$. Thus, adoption of conservation tillage practices can provide a vital path for stabilization of GHG emissions globally. Hence, the adoption of CA practices is very advantageous in improving soil health beside acting as strong adaptation and mitigation measures to climate change.

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# 8. Resource Conservation Technologies for Resource Conservation, Mitigation and Adaptation to Climate Change

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Agricultural productivity depend on natural resources of a region which includes land (over 55 per cent of non forest land), water (about 80 per cent of total fresh water), soil, biodiversity (forests, pastures, and wildlife), and climate. Increasing population and increase in their standard of living are placing tremendous pressure on the natural resources. Furthermore, the increase in productivity is at the expense of deterioration in the natural resource base. The impact of the resource degradation is more on rainfed regions.

Globally 80 per cent of the cultivated area is rainfed and produces 62 per cent of the staple food. Farmers' yields in rainfed regions in the developing countries are low and unstable due to climate change and resource degradation due to over-exploitation of natural resources. Furthermore, the productivity of rainfed crops depends upon the quantity, distribution of rainfall and duration of intermittent dry spells experienced during different growth stages of the crop. Hence, the primary way to unlock the potential of rainfed agriculture in dry areas is by optimal resource conservation technologies without adverse environmental impact is need of the hour. The resource conservation technologies (RCTs) are the practices that enhance resource or input-use efficiency like increasing the nutrient and rain water use efficiency by improving the water conservation to overcome drought spells.

The major rainfed crops are groundnut, redgram, maize, ragi, bajra, castor and cotton etc. Recent experiences in India indicated that participatory demonstration of resource conservation technologies can help farmers to cope with current climate variability, enhance resource or input-use efficiency which primarily focus on resource conservation and have long-term benefits which in turn help in development of sustainable livelihoods.

The first predominant cause for degradation of productive capacity of soils is water and wind erosion and this is more pronounced in rainfed regions. The rainfed soils have high slope which varies from 1 to 10% with low infiltration capacity, added to this high intense rains in this regions is a common phenomena which causes runoff and loss of top layer of fertile soils along with the nutrients, and results in shallow depth of soils and poor ground water. The amount of agricultural land going out of production each year due to soil erosion is about 20 million hectares, and approximately 40 per cent of the world's cropland is now degraded hence natural resource conservation is the basic thing for sustainable agricultural production, the natural resources should be conserved effectively to meet the needs of the future generations. The erosion increases further due to faulty agricultural practices. According to estimation, globally 60-70 t of soil is eroded $ha^{-1}$ every year. Further it is 2-3 t/ha and >10 t/ha of fertile soil is eroded in medium soils and steep sloped soils respectively. On an average, in a year of the total eroded soil, 61, 10 and 29% is deposited elsewhere, reservoirs and into oceans respectively.

Several resource conservation technologies (RCT) were identified by the researchers worldwide. These RCT technologies include ex-situ and in-situ water conservation, adoption of appropriate land use based cropping systems, balance nutrient application/site specific nutrient management, organic nutrient management and conservation agriculture with three principles like minimum tillage, residue cover and crop diversification. These technologies aims at improving agro ecosystem productivity, biodiversity conservation, reduce land degradation, improve rain water use efficiency, ensure the sustainability of forests and manage the sustainability of wildlife, fisheries, and furthermore these technologies in a way help in adaptation and mitigation of the effects of global climate change

*In-situ* rainwater conservation includes deep tillage, land configuration methods like broad bed, conservation furrows, contour farming, graded border strips, mulching which can be made with low cost and energy efficient implements are some of the efficient methods which hold great promise. However, the *in-situ* conservation methods adopted are based on rainfall, soil type, topography, climate and cropping system (Table 1) and land capability classification.

Studies by CRIDA at Hyderabad, Bangalore and Anantapur revealed that more than 80% farmers follow *in-situ* conservation measures like sowing across the slope, opening of dead furrows and key line cultivation since *in-situ* conservation methods are comparatively easier to be adopted by farmers than *ex-situ* rainwater conservation. This in-situ rainwater conservation in rainfed areas is a way to bridge gap between potential productivity of available crop varieties and existing crop yields by improving soil moisture content and reducing soil erosion (Pathak *et al.,* 2009).

**Table 1: Soil and water conservation measures for various rainfall zones**

| **Rainfall** | | | |
|---|---|---|---|
| **<500mm** | **500-750mm** | **750-1000mm** | **>1000mm** |
| • 1. *In-situ* conservation in between rows<br>• 2. Contour cultivation<br>• 3. Dead furrows<br>• 4. Field bunds<br>• 5. Tie bunds<br>• 5. Mulching<br>• 6. Ploughing across the slope | 1. Contour cultivation<br>2. Live bunds<br>3. Field bunds<br>4. *In-situ* conservation in between rows<br>5. Tie bunds<br>6. Mulching<br>7. Dead furrows<br>8. Vertical mulching in black soils. | 1. Vertical mulching in black soils.<br>2. Contour cultivation<br>3. Dead furrows Live bunds<br>4. Minimum tillage<br>5. Graded bunds<br>6. Cultivation of crops across the slope. | 1. Live bunds<br>2. Field bunds<br>3. Graded bunds<br>4. Vertical mulching in black soils. |

Conservation agriculture (CA) CA is an important environment friendly strategy and addresses the resource degradation by arresting and reversing the downward spiral of resource degradation and efficient use of natural resources. The studies conducted in rainfed regions with various cropping systems at CRIDA has shown that the CA records lower yields in the initial years but may overtake conventional tillage subsequently. The added advantage of CA is reduction of soil erosion, improved organic carbon and soil fertility due to addition of crop residues and crop rotation furthermore the reduction in fossil fuel use under no till agriculture results in reduction of GHGs emissions and CA helps in mitigation of climate change by reducing GHGs emission and increasing carbon sequestration. But the key to success of CA is retention of crop residues on the soil and the weed control. The major constraints to adopt CA in rainfed regions is availability of crop residues as the livestock compete for fodder, termite infestation to the residues in rainfed regions is more, weed control and seeding of crops in zero tillage. Studies at CRIDA has shown that the crop residues can be increased by manuplation of harvesting height of the crop, growing of cover crops between widely spaced crops, cultivation of second crop like horse gram after harvest of short duration crop. The crops like pigeon pea, castor can be harvested up to 30 cm ht whereas cereal crops like maize and jowar should be harvested at 60cm ht since the fodder quality and nutrients are better in maize and jowar in the top portions of the crop. So harvesting at 60cm has dual advantage. The harvested above portion is used as fodder and the lower part can be used as crop residues to the soil. It was observed that termite infestation will be more on the crop residues present on the soil surface than the anchored crop residues.

## Soil Amendments

Besides the biological agronomic and engineering measures application of the soil amendments like tank silt in red and sandy shallow soils to improve water holding capacity and application of sand to black soils, organic residues help not only to improve soil texture and structure but reduces the erosion and conserves soil moisture. The silt deposited in the lakes and tanks of villages which is rich in nutrients and organic carbon content can be used . Red and sandy soils are predominant in dryland areas and these soils have low clay content, due to the low clay content, percolation of rainwater is more. Hence, to increase the water holding capacity of these soils, tank silt can be added to the top layers of soil, through which water is stored by reducing deep percolation. Application of silt besides increasing water holding capacity is also a good source of nutrients. Moreover, desilting of tanks improves moisture availability and storage capacity of tanks. Tank silt application reduces soil erosion and prevents the loss of nutrients from soil. Studies at CRIDA have shown that application tank silt increases 10-20% of yield along with 30-40% of increased soil moisture. The quantity of tank silt to be applied to soil depends on clay content of soil. Tank silt can be applied once in every three years. This will help in proper mixing up of silt to the soil whenever rains occur. The major precaution to be taken is to avoid high pH tank silt. The added advantage of tank silt application is desilting of tanks improves storage capacity of tanks. And these tank beds can be used to grow fodder in summer season. Studies at CRIDA have shown that tank silt application improved the crop yields by 10-20% along with 30-40% of increased soil moisture. The quantity of tank silt to be applied to soil depends on clay content of soil. Tank silt can be applied once in every three years. This will help in proper mixing up of silt to the soil whenever rains occur. The major precaution to be taken is to avoid high Ph tank silt.

# 9. Good Agricultural Practices for Soil Health and Carbon Sequestration

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Carbon is found in all living organisms and is the major building block for life on Earth. Carbon exists in many forms, predominately as plant biomass, soil organic matter, and as the gas carbon dioxide ($CO_2$) in the atmosphere, and dissolved in seawater. Soil is a large reservoir of carbon, with about 60% organic carbon in the form of soil organic matter (SOM), and the remaining inorganic carbon in the form of inorganic compounds (e.g., limestone, or $CaCO_3$). It is estimated that SOM stores about twice as much carbon as the atmosphere, and about three times as much as forests and other vegetation. Soil carbon sequestration is the removal of $CO_2$ from the atmosphere through plant photosynthesis, and storage as long-lived, stable forms of soil organic matter that is not rapidly decomposed (Lal, 2008). Changes in soil organic carbon levels can have significant effects on atmospheric $CO_2$ levels.

## How is carbon sequestered in soils?

Through the process of photosynthesis, plants assimilate carbon and return some of it to the atmosphere through respiration. The carbon that remains as plant tissue is then consumed by animals or added to the soil as litter when plants die and decompose. The primary way that carbon is stored in the soil is as soil organic matter (SOM). SOM is a complex mixture of carbon compounds, consisting of decomposing plant and animal tissue, microbes (protozoa, nematodes, fungi, and bacteria), and carbon associated with soil minerals. Carbon can remain stored in soils for millennia, or be quickly released back into the atmosphere. Climatic conditions, natural vegetation, soil texture, and drainage all affect the amount and length of time carbon is stored. In agricultural systems, the amount and length of time carbon is stored is determined predominately by how the soil is managed. A variety of agricultural practices can enhance carbon sequestration in soils. The benefits of these practices as well as their potential hidden costs must be considered when management decisions are made. Though not discussed here, there may also be direct or indirect monetary costs and benefits to farmers to implement these techniques.

## Benefits of carbon sequestration

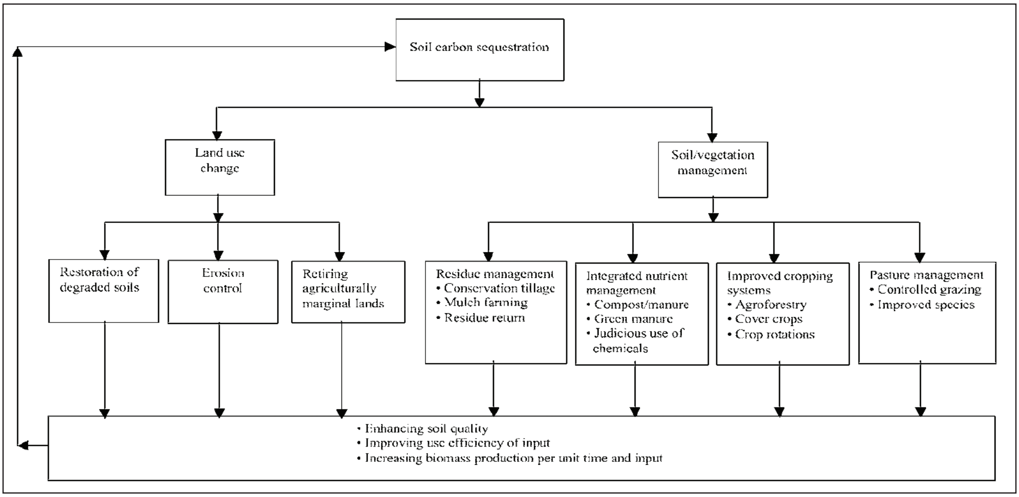
In addition to reducing current atmospheric $CO_2$ levels, increasing soil carbon sequestration can provide other benefits for soil health, the environment, and crop production:

- Improved soil structure
- Increased soil fertility

- Increased infiltration capacity
- Increased water holding capacity
- Increased water use efficiency
- Improved soil health resulting in higher nutrient cycling and availability
- Reduced fertilizer (N, P) needs over the longer term
- Increased agricultural productivity and profitability

## Management practices for soil carbon sequestration

A wide range of the good agricultural practices exist for sequestering organic carbon in agricultural soils. Appropriate practices differ for different soil, crop, and climate conditions. A site-specific approach should be used to select the most appropriate practice to meet local needs by considering all inputs and benefits/costs associated with each input. A life-cycle analysis that considers inputs and associated environmental and economic benefits needs to be carried out. For example, no-till or minimum-till has been identified as one of the best practices to sequester soil organic carbon. However, it may require use of herbicides, which have both environmental and economic implications.




Strategies for soil carbon sequestration

The following management practices can increase soil carbon sequestration and help mitigate climate change.

## Addition of organic soil amendments such as compost, animal manure, biosolids

Manure inputs increase soil organic carbon. Continued input is required in order to maintain higher soil organic carbon level. Once the addition stops, much of the carbon "sequestered" in the soil may be lost due to decomposition. Some residual benefits from manure addition, however, may last for long periods, as improved soil conditions increase productivity and plant residue input into the soil.

The quality of organic carbon inputs is important for soil carbon sequestration. The conversion efficiencies of manure are almost twice that of plant residues. In other words, for constant rates of addition, net soil organic carbon accumulation from manure is nearly twice of that from plant residue additions. It is postulated that the slower decomposition of manure in soils results from the fact that manure consists of largely partially decomposed products. Similarly, products of aerobic composting and anaerobic digestion are also expected to have higher efficiencies for increasing soil organic carbon content than plant materials.

There is an important implication from these results. Soil organic carbon levels have generally decreased upon cultivation. This is partly because of the increased decomposition of soil organic carbon resulting from tillage and partly because of the decreased inputs as a result of the removal of above ground plant biomass. If the above ground biomass is used in animal production and manure is returned to the soil, what is the implication for long-term soil organic carbon sequestration? Approximately one half of the carbon in the animal feed is present in the manure. Since manure is nearly twice as efficient in storing organic carbon in soils, one thus naturally concludes that in an animal production system, if manure is returned to the soil, it will be as effective in maintaining soil organic carbon level as in a natural system in which most of the plant biomass is returned to the soil.

## Reduced tillage

Increased soil organic carbon decomposition from tillage is one of the major factors responsible for the decrease in soil organic carbon content upon cultivation. As a result, avoiding tillage has generally been reported to increase soil organic carbon content. Reducing tillage intensity minimizes or eliminates manipulation of the soil and leaves crop residues on the soil surface. These procedures generally reduce soil erosion, improve water use efficiency, and increase carbon concentrations in the topsoil. Reduced tillage can also reduce the amount of fossil fuel consumed by farm operations. It has been estimated to have the potential to sequester a significant amount of $CO_2$.

## Cover cropping

Cover cropping is the growing of soil covering crops such as mucuna, horsegram for protection and soil improvement between periods of regular crop production. Cover crops improve carbon sequestration by enhancing soil structure, and adding organic matter to the soil.

## Crop rotation

Crop rotation refers to growing a sequence of crops in regularly recurring succession on the same area of land. It mimics the diversity of natural ecosystems more closely than intensive monocropping practices. Varying the type of crops grown can increase the level of soil organic matter. However, effectiveness of crop rotations depends on the type of crops and crop rotation times.

## Enhancing biological N fixation through the use of legume crops

Increasing crop yields increases plant residue input into the soils and thus has the potential of increasing soil organic carbon level. Further, for each legume crop grown, there is approximately 1 ton of $CO_2$-C emission that is avoided in terms of savings on N fertilizer whose manufacture involves fossil fuel burning. The carbon emission savings from using legume plants is permanent while soil carbon content increase resulting from increased inputs must be maintained continuously.

## Including crops/varieties with higher root biomass in the cropping system

There is reason to believe that most of the carbon sequestered in soil originates from roots (Rasse *et al.,* 2005). By virtue of its inherently low decomposability, and their much more intimate interaction with soil particles and aggregates, root carbon has greater opportunity for being sequestered in soil in stable form that carbon applied through plant residues or manures (Srinivas, 2017). Inclusion of crops/varieties with greater root biomass and management practices that encourage better root growth, especially in deeper soil layers can lead to considerable carbon sequestration in soil.

## Avoiding fallow

Fallowing significantly increases the rate of soil organic carbon decomposition. Research results indicate that during fallow the rate of soil organic carbon decomposition is approximately 2 to 2.5 times faster than in a crop year. Thus, to maintain soil organic carbon level, if the fallow frequency is once every two years, the organic carbon input must be 1.5 times higher than in a system with no fallow. As a result, the fallow treatment often results in significantly more soil organic carbon loss than continuously cropped treatment.

## Application of recommended doses of nutrients

The application of adequate nutrients through integrated nutrient management ensures greater crop production, greater root growth and greater availability of biomass for recycling. Long term experiments consistently show improvement in soil organic matter with application of recommended doses of nutrients through integrated nutrient management.

## Biochar

Biochar is a microbially resistant carbon substance which is produced by heating organic wastes such as crop residues or wood chips in the absence of oxygen by a process called pyrolysis. Ordinary biomass fuels are carbon neutral; the carbon captured in the biomass by photosynthesis is eventually returned to the atmosphere through natural processes like decomposition. Sustainable biochar systems can be carbon negative by transforming the carbon in biomass into stable carbon structures in biochar which can remain sequestered in soils for hundreds and even thousands of years.

## Conventional and corresponding improved practices for sequestering carbon in soils

| Conventional practice | Carbon sequestering practice |
|---|---|
| Biomass burning | Residue use as soil cover |
| Tillage and clean cultivation | Reduced tillage, surface residue |
| Fallow | Cover cropping |
| Monoculture | Diversified cropping system – crop rotation/ intercropping/ mixed cropping |
| Low input/subsistence farming | Judicious use of inputs |
| Intensive chemical fertilizer use | Integrated nuttrient management |
| Intensive cropping | Integrtaed farming system with crops, trees, livestock |
| Surface flood irrigation | Subsurface/drip/sprinkler irrigation |
| Cultivation of marginal soils | Conservation reserves/Plantations for restoring degraded lands |

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# 10. Rain Water Management Technologies for Climate Resilience in SAT Regions of Peninsular India

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Rain water is the primary constraint defining the semi-arid tropics (SAT) and is a limiting resource for sustainable agriculture in the SAT. If not managed properly, it affects crop productivity significantly and causes land degradation through runoff and associated soil loss. Out of 140.30 m ha net cropped area in India, nearly 83.90 m ha is the net rain-fed area and the remaining 56.40 m ha is the irrigated area. The SAT is characterized by high water demand with a mean annual temperature greater than 18°C where rainfall exceeds evapotranspiration for only 2 to 4.5 months in the dry and 4.5 to 7 months in the wet-dry semi-arid tropics (Troll, 1965). The coefficient of variation for the annual rainfall ranges between 20 and 30 per cent in these dry regions. Along with the erratic rainfall, increasing population, rising demand of water for non-agricultural uses is proportionally reducing the water availability for agriculture, which is the lifeline for rural poor. Thus efficient management of rainwater through water harvesting and efficient water use technologies is the solution for increasing productivity, reducing poverty and maintaining the natural resource base in the SAT.

The average annual rainfall in India is about 1170 mm. Most rain falls in the monsoon season (June-September), necessitating the creation of large storages for maximum utilisation of the surface run-off. Within any given year, it is possible to have both situations of drought and floods in the same region. Regional variations are also extreme, ranging from a low value of 100 mm in Western Rajasthan to over 11,000 mm in Meghalaya in North-Eastern India. Possible changes in rainfall patterns in the coming decade, global warming and climate change could affect India's water resources.

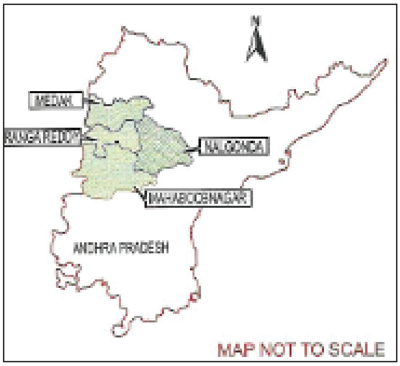
The peninsular India consists of four agri based important states namely Andhra Pradesh, Tamil Nadu, Karnataka and Kerala representing the different topograpy and climate. Andhra Pradesh receives its rainfall both from South-West (SW) and North-East (NE) monsoons. There is a wide variation of the rainfall between the different districts of the State. The six north coastal districts and three north Telangana districts receive more than 1,000 mm per annum, while a scanty rainfall below 700 mm is registered in Kurnool, Anantapur and Kadapa Districts. The lowest is recorded in Anantapur District (568 mm), while Vizianagaram District has the highest rainfall (1,159 mm) on an average.

The average annual rainfall of Tamil Nadu is 912mm. Tamil Nadu occupies 4% of India's geographical area while it has only 3% of the water resources at all India level. The occurrence and distribution of rainfall in the Karnataka is highly erratic. The annual normal rainfall is 1138 mm received over 55 rainy days. It varies from as low as 569 mm in the east to as high as 4029 mm in the west. About 2/3rd of the geographical area of the state receives less than 750 mm of rainfall. Even assured rainfall areas of the State experience scarcity of water during some years. Kerala gets on an average of 307 cm rainfall, the bulk of which (70%) will be received during the South-West monsoon which sets in by June and extends upto September. The State also gets rains from the North-East monsoon during October to December. The state experiences severe summer from January to May when the rainfall is minimum. The two monsoons have a direct bearing on the ground water potential of the State which also follows the same seasonal trend.

## *In-situ* rain water management practices in Peninsular India

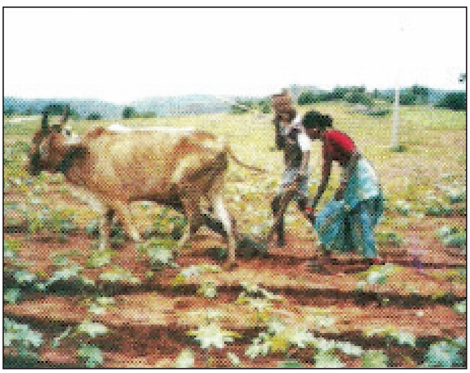
### Conservation furrows:

Castor is an important non-edible oilseed crop grown by the rainfed farmers in Alfisols of southern Telangana. The productivity of this crop in the region is very low due to shallow soils and frequent dry spells. The dry spells occur at early (0-45 DAS), mid (45-90 DAS) and terminal (90-120 DAS) growth stages of the crop and reduce potential yields considerably. This involves management of drought through a package of practices covering (i) sowing of drought tolerant cultivars of castor like Jyothi, Kranti during June 15th to July 7th week across the slope (ii) formation of conservation furrows for every 2 rows planted at 90 cm apart (iii) operation of blade harrow in between castor rows during early growth stage of the crop and iv) additional nitrogen application 10 kg N/ ha after the relief of the dry spells either at early (up to 45 DAS) or mid (45-90 DAS) growth stages of the crop.





Conservation furrows for drought mitigation


Nitrogen application after the relief of dry spell

### Conservation furrows for drought mitigation Nitrogen application after the relief of dry spell

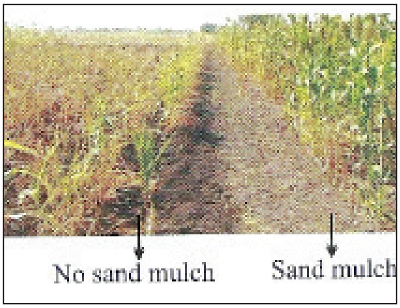
The adoption of drought management practices as a package gives 35-50% higher yields of castor over farmers practice with a B:C ratio of 1.8. The technology is prevalent in the districts of Mahabubnagar, Ranga Reddy, Nalgonda and parts of Medak district in Telengana region.

### Compartmental bunding for moisture conservation

In northern dry zone of Karnataka, *Kharif* cropping is not possible due to workability and tillage related constraints in medium to deep black soils. Further, infiltration rate is low resulting in more runoff. It involves making square compartments on the field to retain rainwater and arrest soil erosion. After receipt of early rains in June and July, land is harrowed to remove germinating weeds. Then compartmental bunds (0.15 m height) are formed using bullock drawn bund former. The size of the bunds varies from 3 m x 3 m to 4.5 m x 4.5 m depending on the slope. The cost of compartmental bunding is Rs.150/ha. These bunds are retained till the sowing of *rabi* crops, which are sown with seed cum ferti drill during second fortnight of September to first fortnight of October. Compartmental bunds provide more opportunity time for water to infiltrate into the soil and help in conserving soil moisture.

### Gravel and sand mulching in sodic soils for moisture conservation

Sodic medium and deep black soils exist on an extent of 2.5 lakh ha in Koppal and Gadag districts in northern Karnataka. The infiltration rate is low and most of the rainwater is lost as runoff in these soils. However, traditionally, some farmers in this region apply locally available gravel and sand mixture as mulch and successfully produce better crops and get more income. The technology involves sand application during summer to sodic vertisols. Before application of sand, perennial weeds like *Cynodon dactylon, Cyperus rotundus* etc. are removed. FYM @ 5 t/ha is applied followed by deep ploughing. After bringing the soil to fine tilth, nearly 275-300 tractors loads/ha of gravel and sand mixture is



uniformly applied and spread manually using spades to ensure uniform thickness of 10 to 15 cm on soil surface. The cost of application of gravel sand is Rs.77500/ha (Rs.2500 for labour cost spreading + Rs.75, 000/- for transportation @Rs 250/tractor load).

### Cover cropping for *in-situ* moisture conservation in black soils

Farmers keep land fallow during *Kharif* in medium to deep black soils of northern dry zone of Karnataka and cultivate sorghum, sunflower and chickpea during *rabi*. This results in splash erosion and high runoff in *Kharif*, which leads to loss of topsoil, decline in soil fertility and crop yields over time.

In order to reduce runoff and splash erosion, cover cropping with quick growing species has been used. These crops include sunhemp, greengram, cucumber, ridge gourd in *Kharif*. These species quickly cover the ground surface in 45 days and reduce run off, conserve rainwater in-situ. Legume cover crops improve soil fertility by adding nitrogen and benefitting succeeding crops when incorporated at harvest or during vegetative stage as in case of sunhemp (at 45 days).

### Ridge furrow and Broad Bed furrow systems for moisture conservation

In South Tamil Nadu region, where the black cotton soils are predominant, were tried with land configuration systems like ridge furrow and broad bed furrow systems. The spacing of furrows was 45 cm and 1.2 m width broad bed was found suitable in black soils. When the systems are grown with sorghum, the BBF gave the maximum yields followed by ridge furrow and flat bed systems. These systems improved the rainwater use efficiency as well as control the erosion within the field and provide efficient drainage to the crop for proper growth and yield. The above technology is very useful to the farmers of the rainfed black soils for improving the productivity and profitability.

## Farm Pond Technology in Peninsular India as Ex-situ runoff water harvesting from farm fields

### Andhra Pradesh

ICAR-CRIDA has optimized the size of farm ponds and catchment command ratios for different runoff co-efficient. 500 $m^3$ capacity farm pond of size 17 x 17 x 3 m and 750 $m^3$ with size 20 x 20 x 3 m have been suggested to implement in medium to high rainfall regions. The minimum catchment required for such farm ponds varies from 2 to 10 ha depending upon the slope, crops and other multiple uses of water. However, there is a scope for increasing the capacity of the farm ponds in high rainfall regions when planned with cropping system and fish culture. Oil seed crops (groundnut, sunflower, sesame, soybean, castor and cotton), pulses (redgram, chick pea, blackgram, green gram) and cereals (sorghum, maize) are popularly grown in rainfed areas of AP like Anantapur, Mahabubnagar, Adilabad, Medak, Nizamabad, Kurnool, Prakasam, Chittor and YSR Kadapa districts. In addition to the above crops, vegetables can also be planned under farm ponds. Lining of farm ponds is required in red soils regions to arrest seepage and black soils have good potential for water harvesting. The cost of the excavation is estimated to be Rs Rs 25-30/$m^3$ of storage. The lining cost of the film (500 micron HDPE/300gsm Silpaulin) is Rs 80-100/ $m^2$.  Supplemental irrigation at critical stages of flowering and pod filling with 50 mm water has improved the yield of groundnut by 65% over the rainfed.

After the establishment of farm pond, he cultivated groundnut in half acre of land. The water stored in the farm pond was sufficient to irrigate and sustain the crop and he was able to harvest 14 bags of ground nut worth of Rs. 15400 (Rs. 1100 per bag). The net income after deducting all the input and cultivation expenses was Rs. 9400.

## Conclusions

The paper deals with different *in-situ* and ex situ rain water harvesting technologies adopted in different regions of peninsular India. Farm pond technology would serve the purpose of climate resilience in rainfed agriculture and found more profitable in black soil regions. The technology will help the farmers to reap multiple benefits from the localised storage of water like fish farming, growing vegetables apart from their traditional crops ensuring both water and food security in the rainfed regions.

# 11. Micro-irrigation System: Design, Installation and Maintenance

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In traditional irrigation methods, the wastages occurring through storage, conveyance and distribution ultimately result in delivering 30 to 35% of stored water for plant uptake. The traditional flood or ridge and furrow method of irrigating field suffers from numerous problems such as considerable seepage, conveyance and evaporation loss; higher energy cost; lower water productivity; irrigation induced soil erosion, leaching of costly agricultural inputs causing sub-surface water pollution. Moreover, this method is supply driven rather than crop-demand driven causing mismatch between need of the crop and the quantity of water supplied.

The recent advances in irrigation technology have made inroads in the cultivation of vegetables and horticultural crops. The frontier technology of micro-irrigation system (MIS) not only provides higher water productivity but also minimize the problems associated with the traditional irrigation system. Application of micro-irrigation system enhances the water use efficiency to 90-95%. In MIS, the water is applied at low rate in the root of the plants more frequently. The major components in successful operation of MIS include design, installation and maintenance.

## Design:

The design of MIS include water balance (accounting gain, loss and change in water storage at particular condition at particular time), estimation of water requirement, operation and frequency of MIS, stages of different crops, roots characteristics etc.

## Irrigation methods for vegetables

Type of irrigation method: The different types of irrigation methods are presented in figure 1.

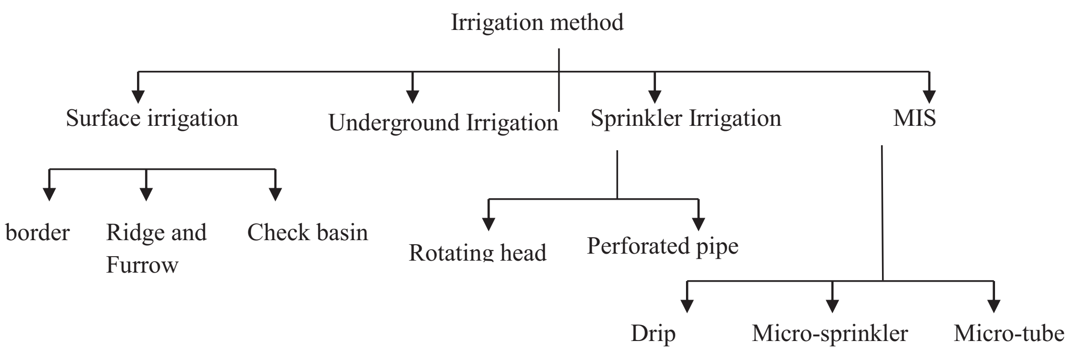

Fig. 1: Types of irrigation methods

*Surface irrigation method*: Water is applied directly to the field using field channels, flooding in check basin using field bunds and ridge and furrow.

*Underground irrigation*: The water is applied under the ground beyond the root of plant.

*Sprinkler irrigation*: The water is applied through high pressure nozzle that causes sprinkling of water droplets in the air simulating the rain.

*Drip Irrigation or MIS*: The water is applied at the root of the plant at low rate and more frequent. Figure 2 presents the different components of standard MIS.

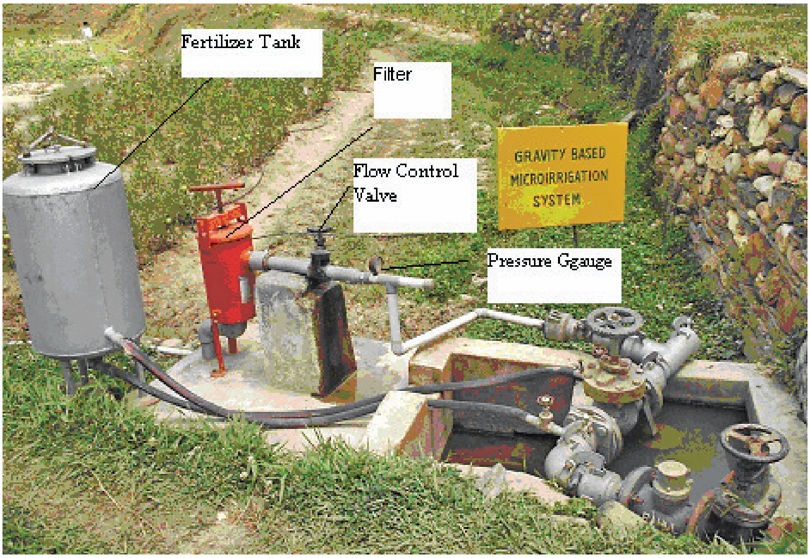


Fig. 2: Major components of micro-irrigation system

In MIS the water is applied at frequent interval in small quantity. The proper management helps in maintaining the adequate moisture and air in the root zone of the plant throughout the crop season. The water conveyance pipe (main and submain and lateral) and water application devices (dripper, emitter and micro-tube) are the integral components of micro-irrigation system. Main and Submain pipes are usually made from PVC or HDPE. Lateral pipes have the diameter of 12 and 16 mm and is made from LDPE. The water application devices are mostly made from PVC. Since all these are made from plastics, these pipes are chemically inert. The irrigation system has fertigation tanks as accessories. Figure 3 presents the major components of MIS.

**Main pipe:** The main pipe has the diameter of 50mm or more and is buried under the ground.

**Submain pipe:** The submain pipe diameter is lesser than the main pipe and is also buried under the ground. If the field is small less than (1 acre) and crop is same, then submain pipe is not needed.

*Lateral pipe*: The lateral pipe that attached the water application devices are kept over the ground. The attachment of water application devices are fixed as per the crop geometry.

*Joiner and accessories*: These are used to customize the irrigation system according to the field conditions. These includes tee, elbow, reducer, connector and end cap.


Filter is one of the major components of MIS, which is used to separate the foreign material from the water to prevent the MIS from frequent clogging. These are classified as media filter and screen filter. The media filter has higher filtration capacity as compared to screen filter.

## Advantage of MIS over traditional irrigation system

### Table 1: Advantage of MIS over flood irrigation system

| S. No. | Description | MIS | Flood Irrigation |
|---|---|---|---|
| 1 | Water Saving | Significantly (40-60% higher than flood irrigation) | Water consumption is more due to higher evaporation and seepage. |
| 2 | Conveyance loss | Almost nil | Significantly higher |
| 3 | Irrigation efficiency | 80-90% | 30-50% |
| 4 | Expenditure | Less on labour, fertilizer and chemicals | Comparatively more |
| 5 | Problem of weeds | Almost nil | Significantly higher |
| 6 | Disease and pest | Less | More |
| 7 | Fertilizer use efficiency | More | Less |
| 8 | Control on water supply | Can be achieved easily | Difficult to control |
| 9 | Benefit : Cost ratio | 1.3 to 13.0 (excluding water saving)<br>2.8 to 30.0 (including water saving) | 1.8 to 3.9 |
| 10 | Increase in productivity | 20-100% as compared to flood irrigation | Significant less than MIS |

**Table 2: Irrigation efficiency under different irrigation methods**

| Irrigation efficiency | Irrigation method | | |
|---|---|---|---|
| | Surface | Sprinkler | MIS |
| Conveyance efficiency | 40-50% (Canal)<br>60-70% (Well) | 99% | 99% |
| Application efficiency | 60-70% | 70-80% | 90% |
| Surface moisture | 30-40% | 30-40% | 20-25% |
| Overall efficiency | 30-35% | 50-60% | 80-90% |

# 12. Geospatial Applications for Water Resources Management


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Rainwater harvesting and providing one or two supplemental irrigation to crops during prolonged dry spells which coincides with the critical growth stages of the crop can increase the yield significantly. Under the changing climatic scenarios, the distribution of rainfall will vary spatially and influence the runoff potential for rainwater harvesting and hence, special attention is needed for the future planning of these water resources. Planning of soil and water conservation interventions needs site specific runoff and soil loss data (spatial) which are scarcely available in developing countries (Sanjay *et al.* 2010). In case of limited availability of these data, SCS-CN is widely used for the quick and accurate estimation of runoff and RUSLE is for estimating soil loss from ungauged watersheds. These methods coupled with GIS helps to estimate the runoff and soil loss spatially and temporally. Identifying the suitable sites for *in-situ* and ex-situ soil and water conservation interventions with the help of survey is one of the giant tasks for planners. Considering the time consumption for conventional geographical surveys for identification of potential sites, a methodology was developed using GIS techniques to find the suitable locations for different soil and water conservation interventions required for increasing the crop productivity.

## Methodology

### Planning interventions based on soil loss

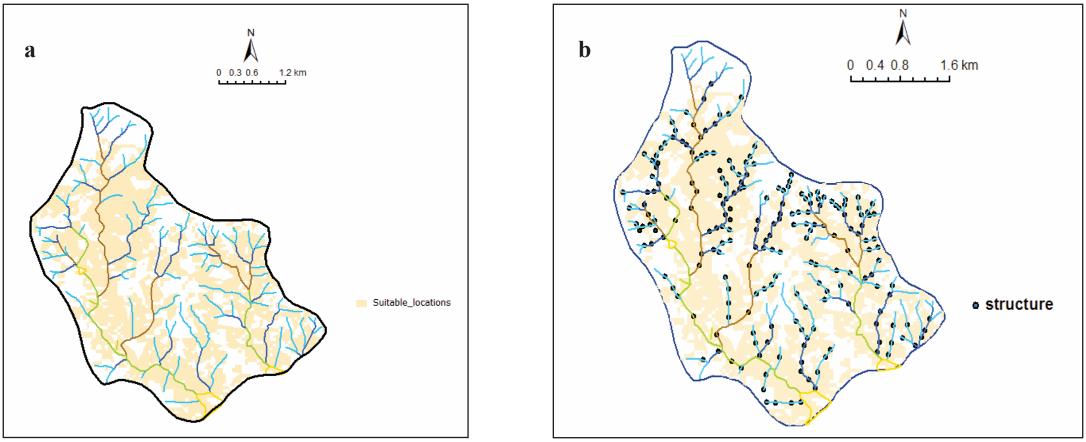
The runoff and soil loss can be measured in the fields using tipping bucket or coshokton wheel and on rivers or streams using automatic gauge recorders. In the absence these data, estimations are preferred.After delineating the watersheds using DEM, soil loss was estimated using RUSLE coupled with GIS (Rejani *et al.,* 2016). The runoff and soil loss estimated were dissolved for the catchments generated in GIS to obtain the soil loss catchment wise and water harvesting interventions were planned based on the soil erosion rate.

### Location specific planning of soil and water conservation interventions based on runoff

The potential sites for different water harvesting structures were planned based on runoff in three stages as described in flow chart (Fig.1) (Rejani *et al.,* 2017).

#### *Stage I: Site suitability*

Location specific identification of suitable sites with the aid of GIS involves the application of a set of primary criteria such as soil, climatic, topographic and hydrologic parameters. In the present study, a set of soil and water conservation interventions like rock fill dams, minor percolation tanks, ponds and check dams were suggested for the watershed taking into account of the watershed characteristics and aforesaid parameters. The guidelines presented in Table 1 were followed at Stage I for the planning of suitable sites for the location specific interventions.




Suitable locations for different soil and water conservation interventions at a) Stage I b) Stage II

**Table 1: Preliminary site selection criteria for the planning of various soil and water conservation structures**

| Structure | Slope (%) | Perme-ability | Runoff coefficient | Stream order | Watershed area (ha) | Soil type | Rainfall (mm) |
|---|---|---|---|---|---|---|---|
| Farm ponds (Shrub land) | 0-5 | Low | Medium/ high | 1-2 | 1-2 | Clay, sandy clay loam | >500 |
| Check dams (scrubs / trees/ river bed) | <15 | Low | Medium/ high | 3-4 | 25 | Clay, sandy clay loam | >700 |
| Check dams (crop land) | <=3 | Low | Medium/ high | 3 | 25 | Clay, sandy clay loam | >700 |
| Percolation tanks (scrub land) | <10 | High | Low | 1-4 | 25-40 | Light sandy soil | >700 |
| Percolation tanks (crop land) | <=3 | High | | 1-4 | 25-40 | Light sandy soil | >700 |

### Stage II: Determination of optimum number of structures

The precise locations and optimum number of structures were determined at Stage II based on the slope, vertical interval, horizontal interval. Singh *et al.,* 1997 reported Cox's formula for calculation of vertical interval.

$$VI = (XS+Y)*03 \qquad (1)$$

where VI = vertical interval; X = rainfall factor; S = slope per centage and Y = infiltration and crop cover factor. The selected study area has moderate rainfall and hence the rainfall factor (X) was selected as 0.6 and infiltration and crop cover factor (Y) as 2.0.

$$NS = \frac{(L\text{-}20)}{HI} + 1 \quad (2) \qquad\qquad HI = \frac{VI}{S} * 100 \quad (3)$$

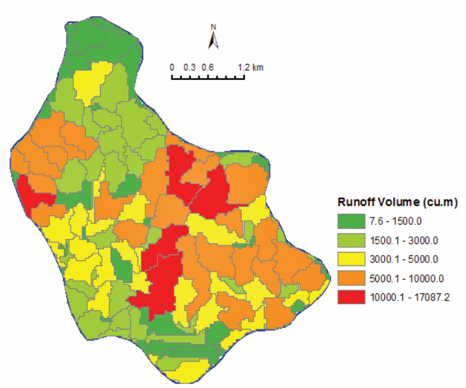
where, NS= number of structures; L = length of drainage channel (m); HI=horizontal interval (m). The optimum number of structures (NS) in drainage lines of micro watersheds was determined using methodology suggested by Rao (2003) at CRIDA. For constructing soil and water conservation structures, at least 20 to 30 m length of flat areas are needed depending upon the size of the structures.

***Stage III: Estimation of surplus runoff and determination of potential sites for structures***

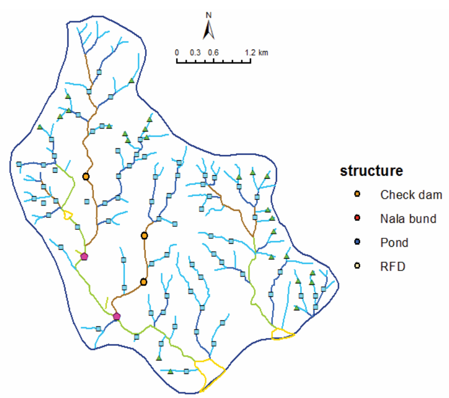
In semi-arid regions, runoff potential availability is very limited. Hence, the final locations and number of structures were optimized based on the spatial availability of surplus runoff after in-situ soil moisture conservation. The suitability map for potential locations identified at Stage III was converted to .kml file, exported to Google Earth and validated with the locations of existing structures by visual interpretation. The additional structures needed were planned after deducting the storage of runoff in the existing structures.

## Conclusions

GIS is very useful for estimating runoff and soil loss spatially from watersheds or large catchments. For finding the suitable locations for different *in-situ* and *ex-situ* interventions,




Surplus runoff potential available after ***in-situ*** water conservation in the watershed




Potential sites determined with the surplus runoff potential available after in-situ moisture conservation (normal year) (Stage III)

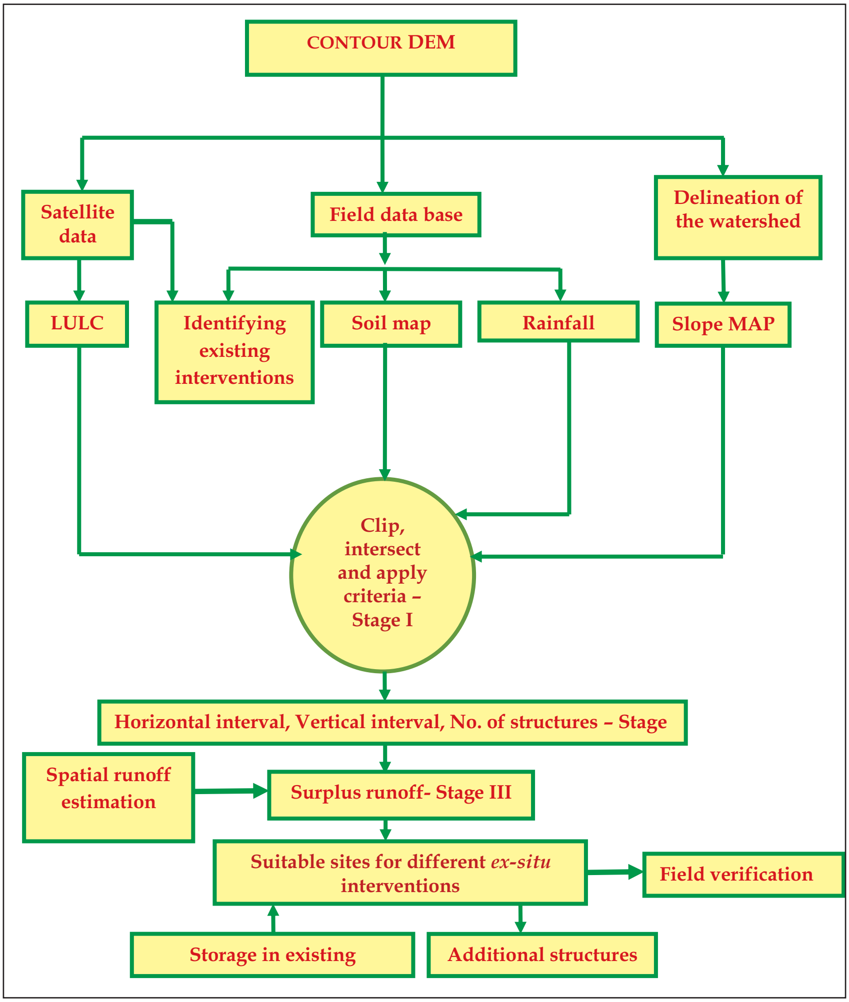



Fig. 1: Flow chart depicting the steps for planning water harvesting structures

different thematic layers were integrated in GIS and the set of criteria was applied in three stages. The specific locations and number of structures was determined based on preliminary criteria, slope of the land, vertical interval and horizontal interval required between structures. Since, semi-arid rainfed regions have limitations in the runoff potential availability; these locations were further optimized based on the surplus runoff available after *in-situ* water conservation. This methodology is less time consuming, more precise and can be utilized for the planning of watersheds or even large catchments.

# 13. Soil and Water Conservation (*in-situ* and *ex-situ*) for Socio-economic Empowerment in Rainfed Areas

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Soil conservation is defined as the control of soil erosion in order to maintain agricultural productivity. Conservation of soil and water resources is important for sustainability of agriculture and environment. Soil and water resources are under immense pressure due to ever increasing population thereby ensuing growing demand for food, fibre and shelter.

Soil and water resources are mainly depleting because of different anthropogenic and natural factors. Soil erosion is one of the processes which results in deterioration of the soil. Soil erosion is removal of soil due to movement of water. Soil erosion may lead to the significant loss of soil productivity and consequently lead to the desertification. Water and wind are the major agencies which are responsible of soil erosion. Deforestation, over-grazing, mismanagement of cultivated soils, intensive cultivation and intensive urbanization are major factors effecting the soil erosion. For sustainable agriculture and environment, it is essential for the protection of soil and water resources. The rate of soil formation is very slow, 1 cm soil is formed for every 100 to 400 years and the enough soil depth is formed in 3000 to 12000 years to have a productive land.

## 1. *In-situ* moisture conservation

This is the process to build adequate soil moisture reserves to combat the recurring dry spells due to intermittent breaks in rain and also avoids inundation. Agroecological (soil type, rainfall pattern and physiography based) specific in-situ moisture conservation measures for improved and adequate rainwater retention with more opportunity time for infiltration.

**1.1 Tillage:** A favourable mechanical manipulation of soil to provide soil condition favourable for crop growth.

**Off-season tillage:** Provides ample time for the soil to get exposed to sun and destroys weeds and pest and better absorption of rainwater.

**Secondary tillage:** Cultivating the soil in a standing crop for removing inter row weeds, forms as soil mulch for good aeration.

**1.2 Contour cultivation:** Cultivation across the slope, along the contour lines to improve water storage in furrow across the slope.

**1.3 Conservation furrow:** After completion of tillage operations, a conservation furrow is opened (may be 3m interval) which helps in rainwater harvesting in low rainfall events and for disposal of surplus water during intensive rainfall events.

**1.4 Green manuring:** Is the cultivation of fast growing, short duration legume crops (horsegram) and *in-situ* incorporation in to the soil.

**1.5 Mulching:** Helps in reducing the impact of raindrops, prevent soil losses, increase infiltration and reduces runoff and evaporation losses.

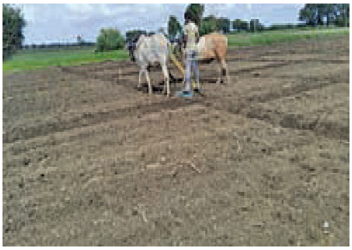
**1.6 Raised bed and sunken bed system:** Consists of alternate raised and sunken beds and size of beds vary with mean rainfall. Runoff from raised bed is captured in adjacent sunken beds supports water tolerant crop (rice) and useful in Vertisols of high rainfall regions (>1000mm).

**1.7 Broadbed and furrow system:** Consists of land configuration with alternative wide (1.5m) beds and furrows. This system suggested for deep to very deep black soils of low to medium rainfall areas (<1000 mm).

**1.8 Compartmental bunding:** Is done in rainy season for *in-situ* conservation and cultivate a *rabi* crop in post rainy season for better crop production and suggested in medium to deep black soils.

Compartmental bunding with dimensions 6 m × 6 m made during *kharif* season for *in-situ* conservation and cultivated a *rabi* chickpea crop during post rainy season recorded the highest yield (624.1 kg/ha) with higher RWUE (2.9 kg/ha-mm) and net returns (Rs.13807/ha) using tractor drawn bund former compared to control (340 kg/ha) and 621.9 kg/ha using bullock drawn compartment bund former when compare to control 327.8 kg/ha (*AICRPDA annual report 2017-18*).

Compartmental bund forming with tractor



Compartmental bund forming with bullock pair

Chickpea under compartmental bunding

## 2. *Ex-situ* moisture conservation

*Ex-situ* moisture conservation involves collection of runoff from treated or untreated catchments and stored in a farm pond, percolation tanks or reservoirs and recycled using energy efficient lifting pumps through micro-irrigation system for protective/ lifesaving/ supplemental/ pre sowing irrigation to crops. Traditional water harvesting structures commonly found in different regions of India are *Tank, Talab, Tanka, Khadin, Nadi* etc. According to Chary *et al*., for designing small ponds, runoff estimates of 100-300 m3/ha is fairly safe in different agroclimatic regions. Either soil cement lining, allowing 10-30% seepage losses or brick tiles with plaster with 0.4% percolation losses can be adopted profitably for lining in most soils except heavy soils. In some heavy soils, even unlined ponds can provide water stored for 2-3 months after the rainy seasons. When harvested water is applied during the long moisture stress period falling in the middle of the growing season, as one irrigation through alternate combined furrow method results in increased yields by 50-100% over the control for most grain crops. An example of rainwater harvesting in farm pond and efficient utilisation under Alfisols of scarcity zone of Andhra Pradesh. The All India Coordinated Research Project for Dryland Agriculture (AICRPDA) centre, Ananthapuramu, Andhra Pradesh recommended farm pond with a dimensions o 10m X 10m X 2.5m with a capacity of 250 $m^3$.

These *in-situ* and *ex-situ* soil water conservation methods are mostly adopted in Integrated Water Management towards the use of land, water and vegetation to combat the drought and floods and to prevent soil erosion and improve water availability for sustainable agriculture production. According to Joshi *et al.* (2005), a study of 311 watersheds across diverse rainfed agroecological regions in India revealed that watershed programmes benefitted farmers through enhanced irrigation areas by 33.5%, increase in cropping intensity by 63%, reduction in soil loss by 0.8 t/ha and runoff by 13% and improvement in groundwater availability with economic benefit of 1:2.14 and an internal rate of return of 22%.

## A case study on Natural resource development for socio-economic empowerment in rainfed areas

Natural resources activities have been implemented under Farmer FIRST Project entitled "Farmers' Centric Natural Resource Development for Socio-economic Empowerment in Rainfed Areas of Southern Telangana Region".

This project was executed in villages of Pudur mandal of Vikarabad district, Telangana, India and was shown in Fig.1 with the objective to initiate a technology development process and develop viable social institutions and linkages for whole village development through active participation of the stakeholders. All the 550 households in 4 villages namely Rakamcharla, Tiurmalapur, Devonoiguda, and Pudugurthy comprise the stakeholders of the project. For increasing the efficiency in utilization of

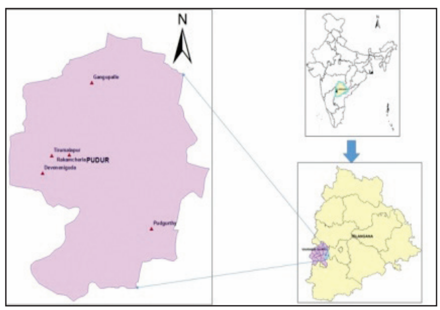



Fig. 1: Location map of Pudur cluster of villages

rainwater harvested through perennial stream surrounding the villages, Gabions structures were constructed across the stream and further enhancing the productivity of vegetable crops, efficient utilization harvested Rainwater through micro-irrigation (drip irrigation) systems were installed in the farmers' field.

## Gabion check dams for rainwater harvesting and for augmenting groundwater recharge:

In watersheds gabion checkdams are constructed in upper reaches to stabilize the gully or stream and reduce the flow velocity and thereby minimize soil erosion. In this project, three plastic embedded (1 mm HDPE film) structures were constructed (Fig.2) and evaluated in the farmers's fields/watershed areas of the project cluster. These gabions were able to store the rainwater in the range of 9000-15,000 m3/structure and conserve the rainwater up to 60%, increasing the water table in the surrounding wells by 0.6 m. The stored rainwater in each structure can provide irrigation to an area of 1 ha.

Fig. 2: Gabion structure (plastic embedded) constructed on the stream

## Efficient utilization of harvested water through micro irrigation systems:

Micro irrigation system (**Fig.3**) for vegetable crops was designed and installed in the field. Due to micro irrigation system farmers were able to plant chilli' and tomato crops earlier. Due to early planting, farmers were able to produce chilli and tomatoes during peak/high prices. Micro irrigation system and fertigation enhanced the productivity and efficient utilization of fertilizer with 60% saving of irrigation water and 35% higher yields.

Fig.3: Micro irrigation system for vegetables constructed on the stream

## Impact of Gabion structures and micro irrigation system:

- Gabion structures constructed on sub streams of FFP villages reduced the soil loss by 70% i.e from 2.1 g/lit - 0.65 g/lit.
- These structures enhanced the ground water table in the surrounding open wells by 1.6 m in monsoon period and 0.9 m in post monsoon season.
- Efficient utilization of harvested rainwater through Micro irrigation system along with fertigation enhanced the productivity up to 35% of higher yield and saving of fertilizer up to 30% and irrigation water 50%.
- Micro irrigation system in the farmers field enabled to plant chillies and tomato crop early to existing planting date and were able to produce chillies and tomatoes during peak season with very high prices made them more profitable.

Fig. 4: Groundwater rise in open wells due installation of Gabions structures constructed on the stream

Fig. 5: Micro irrigation sysytem for efficient utilisation of rainwater for tomato and chillies

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# 14. Metabolic and Molecular Approaches for Enhancing Climate Stress Resilience in Rainfed Crops – Challenges and Prospects

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Plants are exposed to environmental stresses such as drought, elevated temperatures and salinity – both individually, or more commonly, in combination (Ahuja et al 2010; Raza et al 2019). Along with these, the impending climate change catastrophes represent a serious threat for sustainable agriculture (Lobell 2011). The convergence of various stress signaling pathways to a common set of transcription factors suggests the existence of upstream regulatory genes that control plant responses to multiple abiotic stresses (Liu et al 2014). These abiotic stresses cause numerous deleterious effects on plants which include reduced cellular osmotic potential, inhibition of cell division and expansion, reduced membrane integrity, and impaired cellular function and disruption of ion homeostasis. Plant responses to abiotic stresses involve the multifaceted activation of a range of tolerance mechanisms together with production of compatible osmolytes, synthesis of enzymes/compounds that scavenge/quench ROS, production of chaperones that function to protect proteins and membranes and synthesis of water and ion transporters for maintenance of water and ion homeostasis (Maheswari *et al* 2012; Varshney *et al.,* 2011).

A number of adaptive traits have been identified with tolerance to water limited environments such as matching the phenology to the available water supply, early vigor, osmotic adjustment, transpiration efficiency, grain growth, leaf area retention etc. Different physiological mechanisms contributing to heat tolerance in the field are higher membrane thermo stability, stay green, and heat avoidance as indicated by canopy temperature depression and high stomatal conductance. Similarly of a number of plant responses to salt stress over production of compatible solutes, Na+/K+ ratio, ROS, stomatal closure are the most important ones. These adaptive traits in response to various abiotic stresses have the ability to directly or indirectly control yield over a time-scale influencing either water use efficiency and partitioning to the grain (Shankar *et al.,* 2014).

In recent years, crop physiology and genomics have lead to new insights to abiotic stress tolerance providing new tools for crop improvement (Vinocur and Altman, 2005). Development of transgenic plants has undoubtedly opened a new avenue to enhance abiotic stress tolerance in crop plants. Plant engineering strategies for abiotic stress tolerance have been focused largely on the expression of genes involved in osmolyte biosynthesis, enzymes for scavenging ROS, molecular chaperons (HSPS, LEA), transcription of factors, proteins involved in iron homeostasis (Mittler and Blumwald 2010; Varshney *et al* 2011). However, to find tune transgenic technology into a more practical strategy issues like using tissue and stage specific and stress individual promoters; to target multiple gene regulations rather than single genes; developing near natural field stress phenotyping have to be efficiently addressed. Marker assisted selection is another molecular tool which gained considerable importance in developing abiotic stress tolerant genotypes. For developing crop genotypes with enhanced multiple tolerance it is of paramount significance to understand plant responses to abiotic stresses that disturb the homeostasis equilibrium at cellular and molecular level in order to identify a common mechanism for multiple stress tolerance. An integrated approach for developing crop cultivars with better adaptation to multiple abiotic stresses involves use of metabolic and molecular tools for identification of stress signaling pathways and tolerance mechanisms.

## Metabolic and metabolomic approaches:

Metabolic and metabolomics approaches involve signal transduction molecules such as salicylic acid, ABA and acclimation process mediated by antioxidants or osmoprotectants. Plant metabolites implicated in multiple abiotic stress responses comprise compounds such as polyols mannitol and sorbitol; dimethylsulfonium compounds, such as dimethylsulfoniopropionate, glycine betaine; sugars such as sucrose, trehalose and fructan; or amino acids such as proline and ectoine that serve as osmolytes and osmoprotectant to protect plants under extreme salt, drought and desiccation stresses. A variety of epicuticular waxes protect plants from excess water loss during drought and serves as a mechanical barricade to confront pathogens. The saturation level of membrane fatty acids can significantly alter chilling tolerance. Many small molecules protect plants from oxidative damage associated with a variety of stresses. Ascorbic acid, glutathione, tocopherols, anthocyanins and carotenoids protect plant tissues by scavenging active oxygen intermediates generated during oxidative stress. The plant defense response is connected with the production of phytoalexins, activation of the general phenylpropanoid pathway and induction of lignin biosynthesis. Salicylic acid, methyl salicylate, jasmonic acid, methyl jasmonate and other small molecules produced as a result of stress can also serve as signaling molecules activating systemic defense and acclimation responses (Vinocur and Altman, 2005; Trethewey and Krotzky, 2007).

## Transcriptomic Approaches:

Advances in forward and reverse genetic approach have elucidated genes and gene products that are involved in gene expression, signal transduction, and stress tolerance under various kinds of abiotic stresses (Yuan *et al*. 2008). Transcriptomic approach has the potential to identify a large number of genes not previously shown to have a role in regulating stress responses. The importance of micro RNA (mRNA) has to be emphasized in transcriptome analyses. However in the transcriptome profile, it is imperative to scrutinize which mRNAs are translated, degraded, or temporarily stored during stress treatments. It is central to explain the purpose of newly recognized stress-responsive protein-coding and non-coding RNAs to comprehend the multifaceted abiotic stress responses of plants. Integrated metabolome and transcriptome analyses have exposed that numerous vital metabolic pathways are regulated at the transcriptional level (Basheer *et. al.,* 2019).

## Transgenic Approaches:

Early endeavors to develop transgenics for abiotic stress tolerance were concerned with genes responsible for alteration of a single metabolite so as to bestow increased tolerance to various abiotic stresses. Stress proteins with recognized functions such as water channel proteins, key enzymes for osmolyte biosynthesis, detoxification enzymes, and transport proteins were the early objectives of plant transformation (Ashraf and Foolad, 2007). But now transformation efforts with regulatory proteins has been carried out where several genes implicated in stress response can be concurrently synchronized by a single gene encoding stress inducible transcription factor such as *AP2/EREBP, MYB, WRKY, NAC, bZIP* (Golldack, 2011). .

At CRIDA, Morpho-physiological evaluation of several rainfed crops such as sorghum, pearl millet, maize, groundnut, pigeon pea, castor under water deficit stress revealed significant interrelationship between the tolerance traits and grain yield. In maize, genotypes with high yield and very good tolerance across the seasons were identified based on a thorough analysis of drought related morpho-physiological traits and DSI index. Crosses were attempted for both yield and physiological traits using contrasting genotypes and RIL population from trait specific cross for RWC have been developed.

Subtractive suppression hybridization libraries were constructed in pearl millet for water deficit, high temperature and salinity stresses and two novel genes were identified. Also transcription factors such as Calcium dependent protein kinase (CDPK) and universal stress protein (USP) were isolated, cloned and characterized for multiple abiotic stress tolerance.

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# 15. tStress Tolerant Crop Varieties for Managing Climate Variability

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The global demand for food and feed crops is estimated to be double by 2050 (Foley *et al.,* 2011). Globally, rainfed agriculture is practiced in around ~75% of the total agricultural area (FAOSTAT, 2016). Under the climate change scenario, with increasing water scarcity expansion of the area under irrigation does not appear to be a realistic to address the challenge of food security specially in developing countries. Therefore, food security in the twenty-first century will rely increasingly on the release of cultivars with improved tolerance to abiotic stresses and with high yield stability. It is projected that annual daily maximum temperature will likely to increase by about 1–3°C by mid-21st century, and by about 2–5°C by the late 21st century (IPCC, 2012). The impact of a changing climate is not only about temperature increase, but it is also affecting the magnitude of rainfall and its distribution, and therefore it's availability at critical times of the crop cycle (Feng *et al.,* 2013). Improving drought tolerance in crops with increasing water use efficiency and enhancing agricultural water productivity under rain-fed conditions is a number one priority today in a growing number of countries including India.

India's agricultural growth has been phenomenal over last few decades as the country moved from severe food crisis before 1960's to self-sufficiency and surplus food grain production. However, most of this increase in agricultural output could be attributable to green revolution with bringing more areas under irrigated environments and improved high yielding varieties. It is no longer feasible and in fact there is a decline owing to urbanization and rapid industrialization in recent years, to meet the demands of ever-increasing population. Hence, intensification of agriculture through resource use efficiency has to be the main focus as competition for land and water are increasing from non-farm sectors. As a result, feeding the ever-increasing population remains an uphill task with this rapid increase in population along with climatic adversities.

The recent molecular, genomics and bioinformatics revolutions offer some real opportunities for dissecting drought tolerance into component traits, and then using genomic approaches to select plants with favorable alleles at the underlying genes for developing tolerant cultivars. Although some achievements have been reported recently by the private sector, the development of effective systems for breeding complex traits such as drought tolerance continues to be a major challenge in the public sector, despite significant investments in research and development.

Identifying stress tolerant varieties for different agro-ecologies of the country is essential to sustain and accelerate the productivity to meet the increasing demand of food. Therefore, tolerant crop varieties with consistently higher yields under abiotic stresses specially drought is of paramount importance.

## Impact of Climate Change on Agriculture

Indian Agriculture is projected to be adversely affected by the climate change. Therefore, adaptation to climate change is a must for developing resilient agricultural system. For Indian region, the AR5-WGII (IPCC 2014) report projects an increase in frequency of extreme events such as temperatures, rainfall, heat wave, flood, drought and skewed monsoon years. The projections of global climate change include altered average temperatures, rainfall, enhanced atmospheric carbon dioxide and rise in sea level leading to inundation of coastal areas. In recent past it is more evident, as one or the other part in the country is affected by droughts, excessive rains, floods, cyclones, frost, heat wave and other climatic events. The global and regional impacts of projected climate change are expected to be significant on agriculture, water resources, natural ecosystems and food security (IPCC 2014). Although, the impacts of climate change are being experienced globally, countries like India especially small and marginal farmers of rainfed areas are likely to be more vulnerable due to harsher environments and poor coping abilities. It is projected to have adverse negative effects in terms of shifts in seasons, increase in temperatures and changes in rainfall pattern. The crops may encounter major abiotic stresses like drought, flood, heat and cold during its lifecycle, resulting in substantial yield losses. Weather aberrations directly lead to changing in crop duration and affects reproductive processes such as pollination and fertilization. While the indirect effects are largely due to changes in water availability, altered pest, disease and weed dynamics. However, the impacts of climate change are mostly crop specific, as the study showed that the yields of wheat, rice and maize will decrease while it could be neutral or positive with groundnut, soybean and chickpea (Aggarwal, 2018). Rainfed crops will be more vulnerable to climate change because of the limited options for coping with variability of rainfall and temperature. This will result in shift in sowing time and shorter growing season, which may necessitate effective adjustment in sowing and harvesting dates. Frequent and more intense extreme events may become the norm of the day for common farming community.

Water stress at any stage of crop growth cycle will adversely impact the productivity, while terminal droughts are more critical as the reproductive stage is highly sensitive to stresses. This necessitates the development of resilient crop varieties to overcome the adverse impacts of weather aberration in agriculture. In recent past, this has been demonstrated and realized under actual field conditions through successful adoption of flood tolerant rice varieties like Swarna Sub1, drought tolerant and high yielding groundnut variety Narayani in dry areas of

Andhra Pradesh in India. Similarly, in case of wheat, Lok-1 is one the most successful variety grown under heat stress in states of Gujarat, Madhya Pradesh and other areas where crop is exposed to terminal heat stress during grain filling stage and maturity.

## Resilient Crop Varieties for Climate Smart Agriculture

The development, identification and use of climate resilient crop varieties along with different adaptation and mitigation strategies are essential for agriculture to successfully cope with climate variability. It is essential to enhance the productivity and profitability of farming community by minimizing risk in agriculture in order to improve the livelihoods of millions of people dependent on agriculture. While, abiotic stresses trigger a series of responses in plants that include changes in gene expression, signal transduction pathways, metabolic and molecular responses in terms of source and sink relations for adaptation to these stresses. Plant's response to abiotic stresses is crop and variety specific. For example, in case of pigeonpea, higher temperatures will shorten crop duration so that it matures when the wet season is still active, while, sorghum experiences shortening of the vegetative phase relative to the grain-filling phase resulting in increased harvest index. Understanding of photoperiod sensitivity, genetic variation for transpiration efficiency will help in identifying short duration high yielding varieties that escape the terminal drought as well as other impending abiotic and biotic stresses.

To develop stress tolerant varieties, it is essential to identify the traits that maintain and promote the growth and development of plants during the stress period. The tolerance to abiotic stresses is manifested in terms of the ability to cope with resource limitation under stress as well as the ability to recover along with high production potential when stress is relieved. In several crops, genetic control of both stress tolerance and resource-use efficiency is quantitatively inherited involving many loci distributed in different regions of the genome. Quantifying and understanding these genetic relationships is the key to improve productivity of crops by developing climate resilient varieties. Several crop improvement programs are focused on improving productivity with tolerance to various abiotic stresses *viz.*, drought, heat, cold, salinity, flooding etc. There have been tremendous advances in understanding physiology, biochemistry and molecular genetics of plant responses to different abiotic stresses. Number of adaptive traits have been studied and used for improvement of drought tolerance like early vigour, short duration, osmotic adjustment, leaf senescence, stay green habits etc. Stay green habits in plants, usually refer to tolerance against drought-induced post-flowering senescence. Roots also play an important role in adaptation to drought stress. Despite all these information available, improving crops yield for water-stressed conditions remains as a difficult challengefaced by breeders. To overcome this challenge precision phenotyping plays apivotal role for the selection of drought-resilient genotypes for ameaningful dissection of the quantitative genetic traits that determine the adaptiveresponse of crops to drought.

The availability of climate resilient crop varieties along with availability of sufficient quantities of quality seeds to the farmers will help in sustaining the production system. Indian National Agricultural Research System (NARS) including various ICAR institutes and state agricultural universities are working over the years for developing improved varieties of different crops with enhanced tolerance to multiple abiotic stresses. These varieties could be utilized by the farming communities in the event of extreme weather situation.

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# 16. High Temperature Stress Tolerance in Crop Plants

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Diverse environmental challenges due to climate change/variability pose a serious threat to food production for the ever burgeoning human population. Among the ever-changing components of the environment, the constantly rising ambient temperature is considered one of the most detrimental stresses for crop production. The global air temperature is predicted to rise by 0.2°C per decade, which will lead to temperatures 1.8–4.0°C higher than the current level by the turn of the present century. Heat stress due to high ambient temperature is a serious threat to crop production worldwide. Heat stress can be defined as rise in temperature beyond a threshold for a period of time sufficient to cause irreversible damage to the plant growth and development. There are three cardinal points for the types of temperatures that are vital for plant activity.

- Minimum temperature below which no plant growth and development occurs.
- Optimum temperature at which maximum plant growth and development occurs.
- Maximum temperature above which plant growth and development stops.

Temperature requirement of different plants vary for the cardinal points as it is related to the duration of exposure, age of the plant, previous history and other externalities. At very high temperatures, severe cellular injury or even death may occur within minutes which could be attributed to catastrophic collapse of cellular organization. Other direct injuries include protein degradation leading to structural loss and enzyme inactivation and increased fluidity of membrane fluids leading to loss of membrane integrity.

The major morphological symptoms of heat stress include scorching of leaves and twigs and sunburns on leaves, branches and twigs leading to senescence and abscission, shoot and root growth inhibition, reduction in internodes length and fruit discoloration and damage and reduced yield. Gametogenesis and fertilization during reproductive stage are very sensitive phases which are most affected by high temperature stress. At whole plant level major anatomical changes observed are reduced cell size, closure of stomata and curtailed water loss, increased stomatal and trichomaotous density, loss of grana stacking or its swelling, reduced photosynthesis by changing the structural organization of thylakoids, increased xylem vessels of both root and shoot and increased permeability of plasma membrane and damage of mesophyll cells. The major phenological changes observed is increase in rate of growth and development upto a certain temperature and decrease afterwards, decreased leaf gas exchange properties, impaired pollen and anther development, flower drop, hastening of reproductive phase and decreased grain yield.

At metabolic level, one of the major consequences of high temperature stress is the excess generation of reactive oxygen species (ROS), which leads to oxidative stress. Plants alter their metabolism in various ways in response to heat tolerance, particularly by producing compatible solutes called osmolytes that are able to organize proteins and cellular structures, maintain cell turgor by osmotic adjustment, and modify the antioxidant system to re-establish the cellular redox balance and homeostasis. The role of exogenous protectants, the underlying mechanisms for transduction of high temperature stress signals and transgenic approaches are currently being taken to promote high temperature stress tolerance in plants. Heat stress affects all aspects of plant processes like germination, growth, development, reproduction and yield. Heat stress differentially affects the stability of various proteins, membranes, RNA species and cytoskeleton structures and alters the efficiency of various enzymatic processes and hence the rate of metabolism.

High temperature during seed development is associated with a reduction in total yield. Under field conditions the negative effect of high temperature gets amplified if there is also a moisture stress. Both temperature and moisture stress together influence the yield by interfering with seed growth and development. High maximum temperature negatively influences the yield of spring wheat affecting the number of productive tillers per square meter, grain weight, grains per spike and quality of the grain protein. And in cotton, both yield and fiber quality gets affected by non-cardinal temperature regimes. In aromatic and non-aromatic rice cultivars, elevated temperatures, during grain filling period, decrease the amylose content of the grain. At elevated temperatures, with high night temperatures, a marked reduction in the percentage of linoleic acid occurs, apparently due to decreased activity of desaturase enzyme which is essential for the conversion of oleic to linoleic acid. It is now well recognized that reduced yields and altered oil composition occur in sunflower crop that matures under high temperature conditions. Whole ranges of metabolic changes that occur due to abnormal temperature cycle adversely affect the biosynthesis of fatty acids in sunflower. It has been observed that increase in degree of unsaturation in fatty acids composition leads to tolerance to low temperature while decrease in degree of unsatuartion governs tolerance to high temperature by influencing cell membrane thermo-stability.

Development of genotypes with enhanced tolerance to heat stress is necessary for the rainfed situations since the crop production system prevalent under these circumstances are very fragile. High temperature stress tolerance is the ability of some genotypes to perform better than others when subjected to same level of high temperature. In other words we can say that heat tolerance is the ability of plant to grow and produce economic yield under high temperature stress conditions. Sensitivity of a crop/genotype to a particular temperature depends upon severity, duration and phenophase of the crop. High temperature influences the photosynthetic capacity of $C_3$ plants more than $C_4$ plants. There exists tremendous variation within and between species, providing opportunities to improve crop heat stress tolerance through genetic means. We need to characterize large pools of germplasm for genetic variability and identify pertinent traits having agronomic relevance for growth and yield and are easily measurable. Development of molecular markers in selection of natural and breeding populations including wild accessions and genetic transformations with specific genes having recognized relevance can assist in developing genotypes with enhanced temperature stress tolerance in crop plants.

At ICAR-CRIDA, screening of maize genotypes for high temperature stress tolerance have been carried out by staggered sowing during January and February so that the reproductive phenophase of the late sown crop faces high temperatures of April and May. Observations were recorded for various morpho-physiological traits, important metabolites and assay of activities of important enzymes related to sucrose, anti-oxidative stress and nitrogen metabolism in selected genotypes having high and low Anthesis Silking Interval (ASI) values. Various morpho-physiological and biochemical traits having a role in heat stress tolerance were identified. Modulation of the antioxidant systems in heat stress tolerant genotypes of maize may be very vital to counter the oxidative damage caused by environmental stresses at cellular level and thus providing tolerance to such stresses. Results of various experiments carried out will be presented.

# 17. Microbial Consortia for Enhanced Adaptation of Rainfed Crops to Moisture Stress


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## Background

Water is the critical factor for crop production in arid and semi arid regions of the world (Maheswari *et al.,* 2017; Gagné-Bourque et al., 2016). Drought would severely affect the crop production in about half of the arable land by 2050 (Mancosu *et al.,* 2015). Plant beneficial microorganisms have enormous potential to enhance the drought tolerance and crop productivity (de Souza *et al.,* 2015; Bodhankar *et al.,* 2017). They exhibit variety of plant growth promoting characteristics which help in modifying the physiological responses to water scarcity and enhances the survival and growth of crop plants (Desai *et al.,* 2007; Manjunath *et al.,* 2016, 2017; Redman *et al.,* 2011; Morasco *et al.,* 2013).

## Microbial mechanisms for drought tolerance

### Synthesis of biochemical compounds

To prevent the damage to plants under stress conditions, beneficial bacteria increases the synthesis of proline and sugars (Sandhya *et al.,* 2010).

### Modulation of ethylene synthesis

The ACC deaminase producing bacteria inhibits the synthesis of ethylene under stress conditions and help plants survival (Gamalero and Glick, 2015).

### Synthesis of exo-polysaccharides

Biofilm producing bacteria retains more water around them and improves soil moisture content thereby help plants tolerate drought conditions (Batool and Hasnain, 2005; Bashan and Holguin, 1997).

### Production of phytohormones

Phytohormones *viz.*, indole acetic acid (IAA), gibberlic acid (GA) and absicic acid (ABA) produced by the microorganisms help plants tolerate moisture stress conditions.

## Root growth improvement

Beneficial bacteria enhance the root length and root volume of plants so as to improve the water uptake of plants under stress conditions (Armada *et al.* 2014).

### Regulation of gene expression

Plants switch on /off certain genes for their survival under stress conditions. Over expression of trehalose-6-phosphate synthase gene (ReOtsA) in common bean (*Phaseolus vulgaris* L.) by *Rhizobium etli* improves the adaptation to moisture stress (Suarez *et al.,* 2008).

### Manipulation of microbiome

Microbiomes comprise of complex group of micobes (Rascovan *et al.* 2016). Understanding of crop specific microbiome would help to modify the microbiome to get desired benefits (Tkacz Poole *et al.,* 2015; De-la-Pena *et al.,* 2014).

## Microbial consortia developed by ICAR-CRIDA for drought tolerance and plant growth promotion

Combination of microbial cultures carries out multiple functions, which are not possible for a single species /strain. Moreover, consortia are strong and not easily get affected by environmental alterations as individual microbial cultures (Lindemann *et al.,* 2016). With this backdrop, work was initiated at ICAR-CRIDA to develop microbial consortia for drought and heat stress management and plant growth promotion in rainfed crops.

1. ***Pseudomonas putida* P7 + *Bacillus subtilis* B30**

   Application of this consortium to seeds led to significant increase in shoot, root and dry biomass, proline, total sugars and chlorophyll content of sorghum seedlings. In field studies, full dose of chemical fertilizers along with consortium inoculation improved plant growth and yield of sorghum by 10% over chemical fertilizers alone.This consortium is also effective in improving the germination and survival of mustard under heat stress conditions.

2. ***Pseudomonas putida* P45 + *Bacillus amyloliquefaciens* B17**

   Use of this consortium increased the yield of sunflower and sorghum upto 15-20% under rainfed conditions.

At present, the above two consortia are being evaluated at different rainfed regions *viz.*, Ballowal Saunkhri, Parbhani, and Vijayapura in Maize, *kharif* Sorghum and *Rabi* Sorghum, respectively. The seed + soil application of consortia 1 and consortia 2 recorded highest grain yield in Maize and in *kharif* Sorghum respectively. In *Rabi* Sorghum, seed + soil application of consortia 1 recorded highest yield.

### Benefits of using microorganisms/consortia in rainfed agriculture

- Consortia of beneficial microorganisms help adaptation of rainfed crops to moisture stress by regulating the synthesis of osmolytes like proline and sugars
- Improves plant growth and yield
- Improves soil fertility and activity of microorganisms
- Decreased cost of production
- 10-20% increase in yield
- Component of organic farming in drylands

# 18. Increasing Atmospheric $CO_2$ Concentration and Temperature- Impact on Productivity of Rainfed Crops


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The changes in the composition of atmosphere in terms of greenhouse gases, aerosols influence the properties of solar radiation and alter the energy balance of the climate system. Now it is evident from various studies that the human activities are contributing significantly for the change in climate compared to natural variability in climate. General circulation models predict temperature rises of 1.4-5.8°C by 2100, associated with carbon dioxide increases to 540-970 parts per million. The atmospheric concentration of carbon dioxide- the most important anthropogenic greenhouse gas increasing at alarming rates (1.9 ppm per year) in recent years than the natural range concentration growth rate. This could be due to enhanced usage of fossil fuel and changed land use pattern to some extent.

The carbon dioxide level in the atmosphere has been rising and that this rise is due primarily to the burning of fossil fuels and to deforestation. Measured in terms of volume, there were about 280 parts of $CO_2$ in every million parts of air at the beginning of the Industrial Revolution, and this is 407 ppm today, a 30 per cent rise. The annual increase is 1.9 ppm, and if present trends continue, the concentration of $CO_2$ in the atmosphere will double to about 700 ppm in the latter half of the 21$^{st}$ century.

Carbon dioxide is the basic raw material that plants use in photosynthesis to convert solar energy into food, fiber, and other forms of biomass. In the presence of chlorophyll, plants use sunlight to convert carbon dioxide and water into carbohydrates that, directly or indirectly, supply almost all animal and human needs for food; oxygen and some water are released as by-products of this process. Voluminous scientific evidence shows that if $CO_2$ were to rise above its current ambient level, most plants would grow faster and larger because of more efficient photosynthesis and a reduction in water loss. There are two important reasons for this productivity boost at higher $CO_2$ levels. One is superior efficiency of photosynthesis and the other is a sharp reduction in water loss per unit of leaf area. By partially closing the stomata, higher $CO_2$ levels greatly reduce the plants' water loss- a significant benefit in arid and semi arid climates where water is limiting the productivity.

There are marked variations in response to $CO_2$ among plant species. Most green plants, including most major food crops use the C3 pathway respond most dramatically to higher levels of $CO_2$. Under enhanced levels of atmospheric $CO_2$ the increased photosynthesis making C3 plants more efficient. Corn, sugarcane, sorghum, millet, and some tropical grasses use the C4 pathway, also experience a boost in photosynthetic efficiency in response to higher carbon dioxide levels, however the improvement is smaller than in C3 plants. Since these crops are frequently grown under drought conditions of high temperatures and limited soil moisture, this superior efficiency in water use may improve yields when rainfall is even lower than normal. When there was no stress, elevated $CO_2$ reduced stomatal conductance by 21.3 and 16.0% for $C_3$ and $C_4$ species respectively. The lowest response to higher $CO_2$ levels is usually from the CAM plants, which include pineapples, agaves, and many cacti and other succulents. CAM plants are also already well adapted for efficient water use.

Field crops under drought often experience two quite different but related and simultaneous stresses: soil water deficit and high temperature stresses. Elevated $CO_2$ increase growth, grain yield and canopy photosynthesis while reducing evapotranspiration. During drought stress cycles, this water savings under elevated $CO_2$ allow photosynthesis to continue for few more days compared with the ambient $CO_2$ so that increase drought avoidance. Elevated atmospheric $CO_2$ concentration ameliorates, to various degrees, the negative impacts of soil water deficit and high temperature stresses.

Both the mean and extreme temperatures that crops experience during the growing season will change in both temperate and tropical areas. Extreme temperatures are important because many crops have critical thresholds both above and below which crops are damaged. Majority of the crops tend to respond negatively, when the temperature exceeds optimum range and leads to reduced yield. However, the optimum temperature of different crops and their vulnerability to high temperatures varies with the genotype, developmental stage and duration of exposure. High temperature during the reproductive stages causes deleterious effects on the yield and quality. Exceeding crop-specific high temperature thresholds may result in a significantly higher risk of crop failure.

As vegetative and reproductive process have different responses to temperature therefore show different stimulations by $CO_2$ at elevated temperature, hence beneficial effects of elevated $CO_2$ on photosynthesis, carbohydrate metabolism and vegetative growth are not always reflect in seed yield. When the sunflower crop experienced maximum temperature of below 35°C during the anthesis and grain filling stages, the elevated $CO_2$ (550ppm) improved total biomass and seed yield while the response was reduced when it was exposed to more than 40°C. The FATE studies with groundnut at elevated canopy temperature (eT) recorded reduction in total biomass and seed yield while the presence of elevated $CO_2$ (550ppm) at high temperature reduced the ill effects of high temperature showing the protective effect of elevated $CO_2$ against high temperature.

The impact of the future predicted increased $CO_2$ and temperature coupled with changes in precipitation patterns for majority of rainfed crops appears to be not that distressing. However to counter the adverse effects of climate change on agriculture, it is desirable to select the crops and their cultivars thereof, that can better utilize the increased concentration of $CO_2$ and perform better under high temperature and moderate moisture deficit conditions. Understanding the weather variables over a period of time and setting the management practices for better harvest is required for the growth of agricultural sector as a whole.

# 19. Effect of Elevated $CO_2$ and Elevated Temperature on Food Quality and Mineral Composition

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Global climate change models predict increase in atmospheric [$CO_2$] concentration to 700 ppm by 2100 and temperature by up to 2.6°and 4.8°Cby 2065 and end of twenty-first century, respectively (IPCC, 2013).Elevated carbon dioxide and temperatures due to global climate change affect crop yield and seed quality (Prasad *et al.,* 2005; Taub *et al.,* 2008; Uprety *et al.,* 2010), including chemical composition (Uprety *et al.,* 2010). Increased concentration of atmospheric carbon dioxide stimulates crop growth by the carbon fertilization effect (Rogers and Dahlman, 1993). Global climate change, due to human activities, such as $CO_2$ emission, or naturally caused threatens human life as it affects food security and human survival (Prasad *et al.,* 2005; Uprety *et al.,* 2010; Thomas *et al.,* 2003; Taub *et al.,* 2008). The responses of crops to elevated $CO_2$ are highly dependent on temperature (Polley, 2002). Thus, understanding how crop species respond to global environmental changes is crucial for maximizing the potential benefits of elevated $CO_2$ and adjust agricultural practices with the increases in temperature and $CO_2$ (Challinor and Wheeler, 2008). Impact assessment on physiological and biochemical processes indicated that $CO_2$ and temperature are predicted to have significant changes in biochemical composition of grains and their nutritional quality (Stafford, 2007 & 2008; Uprety *et al.,* 2009). Previous studies on elevated $CO_2$ and temperatures showed a decrease in the concentration of mineral nutrition quality, such Ca, S, Mg, Fe, and Zn, in plants, which has a potential negative impact on human nutrition sources. Nutritional proximates were estimated in legume crops grown under atmospheric elevated $CO_2$ concentration and elevated temperature in this study.

## Effect of elevated $CO_2$ and elevated temperature on mineral content

The impact of elevated crop canopy temperature (eT) and its interaction with elevated $CO_2$ (eT + e$CO_2$) on phyto - chemical and nutritional parameters of two black gram (LBG- 752 and T - 9) and green gram (LGG- 460 and WGG- 42) genotypes and one pigeon pea genotype (PRG - 176) was assessed under Free Air Temperature Elevation (FATE) facility. The results revealed that among the two genotypes of black gram, LBG- 752 recorded higher Fe content and Zn under control whereas lower Fe and Zn in T-9 under elevated temperature and carbon dioxide (Fig. 1). Among the two genotypes of green gram, LGG - 460 recorded significantly higher Fe content and Zn content under control whereas lower Fe and Zn was found in WGG-42 under elevated $CO_2$ and elevated temperature (Fig. 1). In pigeon pea (PRG-176) higher content of Fe and Zn was found under control whereas reduced Fe and Zn was found under elevated $CO_2$ and elevated temperature (Fig. 1). Most of the nutrients in grains result from the mobility of nutrients from vegetative pools (source) to grain filling. The decrease of macro and micro nutrients, shown by our findings, was also noticed in other species such as wheat and rice. Elevated temperature and elevated carbon dioxide resulted in decrease of Fe and Zn, cross the genotypes in our studies. Growing evidence has shown that $CO_2$ led dilution effect could reduce mineral content in milled rice with unbalanced translocations of minerals from vegetative parts such as leaf, stem and husk to the grains (Yang *et al.,* 2006). It was also reported that the effects of $CO_2$ magnitude on grain quality will depend on the level of future CO2atmospheric concentration, its interactions with the biotic (genotype, species, diseases, and pathogens) and abiotic stresses (elevated temperature, drought, and soil conditions) and agronomic practices (irrigation and growth conditions) (Uprety *et al.,* 2010).

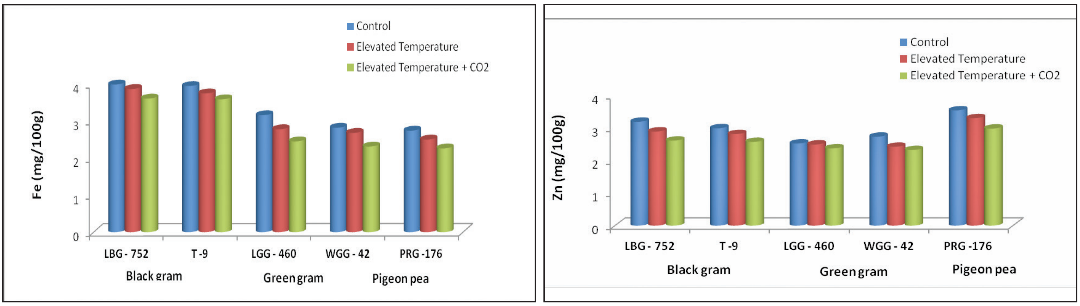



Fig. 1: Effect of elevated $CO_2$ and temperature on Fe and Zn content of legume crops

## Effect of elevated $CO_2$ and elevated temperature on protein content and total carbohydrates

The nutritional quality regarding protein and total carbohydrates of black gram, green gram and pigeon pea showed that black gram genotype LBG-752 found to possess significantly higher content of protein under control, whereas reduced content of protein was found in T-9 under elevated $CO_2$and elevated temperature (Fig. 2).

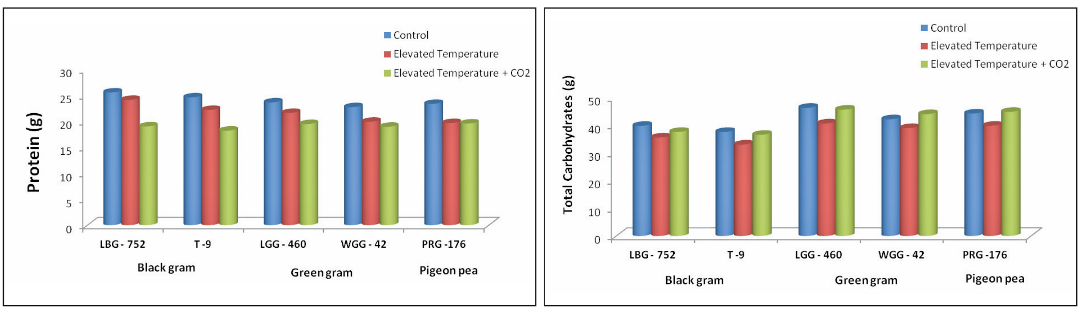


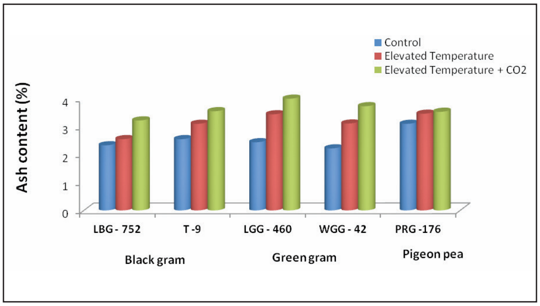

Fig. 2: Effect of elevated $CO_2$ and temperature on protein and total carbohydrates content of legume crops

Green gram genotype LGG-460 having significantly higher protein content under control, whereas lower content was found in WGG-42 under elevated $CO_2$ and elevated temperature. In pigeon pea genotype, PRG-176 was containing significantly higher protein content (23.37%) under control, whereas protein content was reduced (19.58%) under elevated $CO_2$ and elevated temperature.

The total carbohydrates of black gram genotype LBG-752 was found to possess significantly higher content under control, whereas lower content was found in T-9 under elevated temperature. Greengram genotype LGG-460 found significantly higher carbohydrates content under control, whereas lower content of total carbohydrates was found in WGG-42 under elevated temperature. Pigeon pea genotype PRG-176, found higher carbohydrates content under control, whereas lower content of total carbohydrates was found under elevated temperature. Dilution of nitrogen content due to increased photosynthesis and accumulation of carbohydrates under e[$CO_2$] has been associated with reduced seed protein (Uprety *et al.,* 2010; Panozzo *et al.,* 2014). In a number of $C_3$ cereal and legume crops Myers *et al.* (2014) found that e[$CO_2$] under field conditions significantly depressed the level of protein along with iron and zinc in the edible portions of these crops. The reason for low protein concentration in these crops could be due to inference of nitrogen (especially nitrate) assimilation by high [$CO_2$].

## Effect of elevated $CO_2$ and elevated temperature on ash content and crude fiber content

The nutritional quality of total ash and crude fiber content in legume crops grown under three treatments revealed that between two genotypes of black gram, ash content was significantly higher in T-9 grown under elevated $CO_2$ and elevated temperature whereas lower ash content was found in LBG-752 under control (Fig. 3).



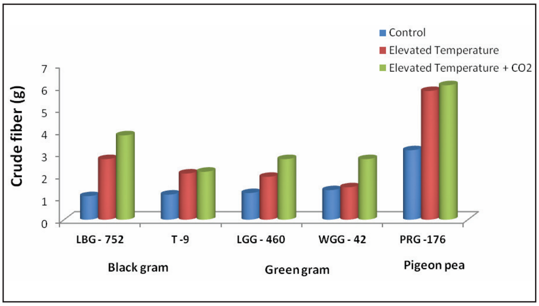




Fig. 3: Effect of elevated $CO_2$ and temperature on ash content and crude fiber of legume crops

Among the green gram genotypes, significantly higher ash content was observed in LGG-460 under elevated $CO_2$ and elevated temperature and lower ash content was found in WGG-42 under control. Among three treatments, in PRG-176 pigeon pea genotype, higher ash content was found under elevated $CO_2$ and elevated temperature whereas, lower ash content found under control.

The crude fiber content of black gram genotype LBG-752 found to possess significantly lower content under control, whereas higher crude fiber content in T-9 genotype under elevated $CO_2$ and elevated temperature. Green gram genotype LGG-460 found significantly lower crude fiber content under control, whereas higher content found in LGG-460 and WGG-42 under elevated $CO_2$ and elevated temperature. Pigeon pea genotype PRG-176 found significantly lower crude fiber content under control, whereas higher content found under elevated $CO_2$ and elevated temperature. Elevated $CO_2$ levels increased the ash content as compared to other treatments, which may be attributed to higher C/N ratio and increased carbon under influence of more photosynthetic activity due to elevated level of $CO_2$ (Sreedevi *et al.,* 2015; Meena Kumari *et al.,* 2017).

## Effect of elevated $CO_2$ and elevated temperature on cooking time

Cooking time was found lower) in LBG-752 genotype of black gram under control, whereas higher cooking time was found in T- 9 under elevated $CO_2$ and elevated temperature (Fig. 4). In green gram genotypes, lower cooking time was found in LGG-460 under control, whereas higher cooking time was found in WGG-42 under elevated $CO_2$ and elevated temperature. Similarly pigeon pea genotype PRG-176 found significantly lower cooking time under control, which is significantly higher cooking time under elevated $CO_2$ and elevated temperature.

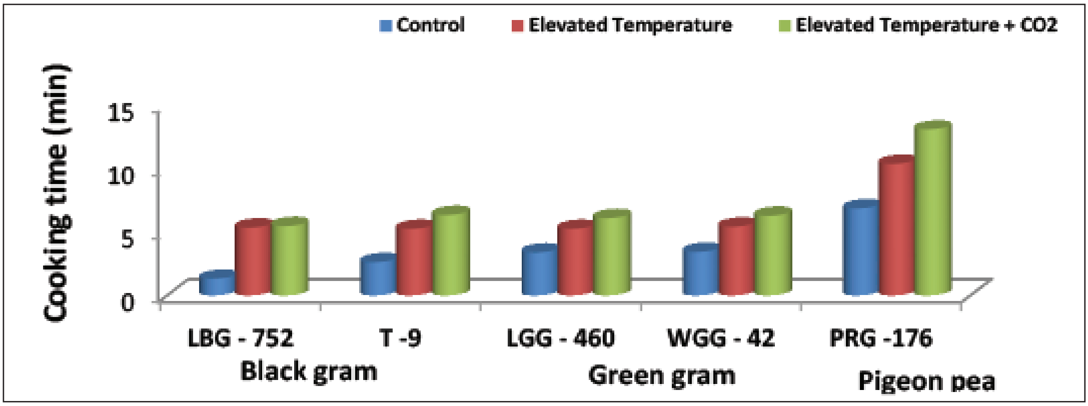



Fig. 4: Effect of elevated $CO_2$ and elevated temperature on cooking time of legume crops

## Conclusion

Rising atmospheric $CO_2$ and elevated temperature levels have a negative impact on the nutritional quality of legumes. Elevated [$CO_2$] and elevated temperature decrease the concentration of a number of nutrients which are important for human nutrition in the edible parts of these legume plants. It decrease the concentration of protein, phosphorus along with important micronutrients including iron, zinc, calcium, copper and increase in ash content, crude fiber. Role of mineral elements in grain development and physiology is another aspect that warrants systematic investigation to simultaneously improve legumes nutritional quality under future climate. Finally, exposure elevated $CO_2$ and elevated temperature would further exacerbate the negative impact on legumes seed quality and mineral nutrient composition seen with the nutrient dilution. Among the three legumes, black gram genotype LBG-752, green gram genotype LGG-460 and pigeon pea genotype PGR-176 are withstanding the elevated $CO_2$+ elevated temperature regime. Thus results indicate that rising $CO_2$ and elevated temperature levels can compromise the general nutritional quality by reduced concentration of many essential nutrients in commonly consumed legumes such as black gram, green gram and pigeon pea.

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# 20. Crops and Cropping Systems for Climate Smart Agriculture


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One of the age old strategies across the world's agriculture in managing water deficits or excesses is growing cropping systems, be it intercropping, sequence cropping and relay cropping etc. However the cropping period needs to match with the rainfall availability as there seems to be a shift in receipt of regular and well spread rainfall to later periods lately. This strategy is to take advantage of the existing situation by manipulating the sowing time, planting various suitable crops for better resource use (Olesen *et al.,* 2011)

## Choice of crops and varieties

The shifts or changes in rainfall trends, rise in temperatures, sudden downpour of high intensity rains etc warrant growing of crops which face these extreme weather conditions ably and further the cultivars which are of shorter duration may be preferred. Although suitable drought or heat tolerant crops are available, the better market price provision would help in farmer preference.

## Improved Intercropping systems

**Sequence systems:** Intercropping systems is the most popular of all the systems, however, area under intercropping is declining due to labour scarcity, hiked labour wages and non availability of intercrop specific herbicides for the control of weeds and constraints in usage of herbicides etc. In order to regain the area under intercropping which is a risk reduction strategy for both water deficits and excesses, strip intercropping with horsegram sequence cropping is suggested (Maruthi *et al.,* 2017). This cropping in the form of strips avoids phytotoxicity to a major extent on intercrop when base crop suitable herbicide is sprayed and it is possible to maintain both the crops independently.

## Relay systems

Receipt of Initial poor monsoon rains, followed by heavy rainfall at the end of the monsoon and post monsoon season would support sowing of a relay crop of horsegram in the rainfed lands of SAT India. When sown at the half crop growth period of first crop, the rain events received during post monsoon would be encashed for the successful second crop as at times, sequence cropping looses the opportunity of capitalizing on extra rain events received. This could be tried in individual crops as well as in the cropping systems.

## Crop Management

Optimization of crop management for extreme weather conditions through the in-situ water conservation measures such as formation of conservation furrows for every two rows, ex-situ water conservation technologies like digging farm ponds and the efficient water distribution systems is necessary in agriculture and more so in rainfed agriculture.

## Crop Diversification

Agro-forestry, a crop diversification practice could contribute to adaptation to climate change and helps in maximixing the use of soil and water resources (Nguyen *et al.,* 2013)

Cropping systems to mitigate the climate change as well as adapt to climate change, the integration of crop management practices would be required. Besides this, breeding tolerant varieties, improved assessing and monitoring of weather parameters to establish pest and disease tolerance in new varieties, various local criteria like market prices would establish climate smart agriculture.

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# 21. Impact of Climate Change on Crop Disease Interactions

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## Introduction

Modern commercial agricultural systems are constantly under threat of outbreak of disease epidemics. In conventional agricultural systems, crops and their pathogens established a harmony and hence, equilibrium was established through a natural evolution process over decades. This equilibrium also included biocontrol systems wherein other living organisms were parasitizing the plant pathogens. This equilibrium helped in minimal crop losses due to diseases. However, increasing pressure on food security demanded increased agricultural output and there by disturbing the equilibrium. Hence, the global agriculture started experiencing the outbreak of epidemics of crop diseases leading to severe losses. While this development took place on one side, the environmental pollution has become additional variable to be reckoned with which had impacts on all biological systems. The elevated $CO_2$ levels coupled with increasing temperatures do affect host-pathogen interactions.

## Elevated $CO_2$ and host-pathogen interactions

Under elevated $CO_2$ levels, the morpho-physiology of the crop plants is significantly influenced. The available data clearly suggests that atmospheric $CO_2$ enrichment asserts its greatest positive influence on infected as compared to healthy plants. This influence in turn will modulate the balance of co-evolution between the host and the pathogen as well as pathogen and biocontrol agent. Elevated carbon dioxide [$ECO_2$] and associated climate change have the potential to accelerate plant pathogen evolution, which may, in turn, affect virulence. Under $ECO_2$ conditions, mobilization of resources into host resistance through various mechanisms such as reduced stomatal density and conductance, (Hibberd *et al*., 1996a, 1996b); greater accumulation of carbohydrates in leaves; more waxes, extra layers of epidermal cells and increased fibre content (Owensby, 1994); production of papillae and accumulation of silicon at penetration sites (Hibberd *et al*., 1996a); greater number of mesophyll cells (Bowes, 1993); and increased biosynthesis of phenolics (Hartley *et al*., 2000), increased tannin content (Parsons *et al*. 2003) have been reported. Malmstrom and Field (1997) reported that $CO_2$ enrichment in oats may reduce losses of infected plants to drought and may enable yellow dwarf diseased plants to compete better with healthy neighbors. On the contrary, in tomato, the yields were at par (Jwa and Walling, 2001). Similarly, Tiedemann and Firsching (2000) reported yield enhancement in spring wheat infected with rust incubated under $ECO_2$ and ozone conditions. Chakraborty and Datta (2003) reported loss of aggressiveness of *Colletotrichum gloeosporioides* on *Stylosanthes scabra* over 25 infection cycles under $ECO_2$ conditions. On the contrary, pathogen fecundity increased due to altered canopy environment. McElrone *et al*. (2005) found that exponential growth rates of *Phyllosticta minima* were 17% greater under $ECO_2$. Simultaneously, in the host *Acer rubrum*, the infection process was hampered due to reduction in stomatal conductance by 21-36% and thereby leading to smaller openings for infecting germ tubes and altered leaf chemistry. Reduced incidence of Potato virus Y on tobacco (Matros *et al*., 2006), enhanced glyocellin accumulation (phytoalexins) after elicitation with ß-glucan in soybeans against stem canker (Braga *et al*., 2006) and reduced leafspot in stiff goldenrod due to reduced leaf nitrogen content that imparted resistance (Strengbom and Reich, 2006) have been reported. Lake and Wade (2009) have shown that *Erysiphe cichoracearum* aggressiveness increased under elevated $CO_2$, together with changes in the leaf epidermal characteristics of the model plant *Arabidopsis thaliana*. Stomatal density, guard cell length, and trichome numbers on leaves developing post-infection increased under $ECO_2$ in direct contrast to non-infected responses. As many plant pathogens utilize epidermal features for successful infection, these responses provide a positive feedback mechanism facilitating an enhanced susceptibility of newly developed leaves to further pathogen attack. Furthermore, screening of resistant and susceptible ecotypes suggests inherent differences in epidermal responses to elevated $CO_2$. Gamper *et al*. (2004) noted that colonization levels of arbuscular mycorrhizae tended to be high on *Lolium perenne* and *Trifolium repens* grown under $ECO_2$ which may help in increased protection against stresses.

With the climate -variability and –change, two types of scenarios are possible that could have bearing on crop diseases. Under low moisture and high temperatures, organisms such as *Macrophomina phaseolina* that cause dry root rots may cause severe yield losses. Under low temperature and high humidity conditions, *Pythium* and *Phytophthora* could of serious concern for many field crops. On pigeonpea, it was observed that during high rainfall years, intensity of Phytophthora blight was also very severe. In sugarbeet, humid conditions favoured *Cercospora* and *Ramularia* significantly. Low temperature and high humidity may also promote wilt pathogens. Excessive irrigation, which can be compared to that of frequent and high intensity rainfall effects, led to the increased intensity of sugar beet leaf and crown wart. It was also presumed that Rhizomania virus, a major concern for sugar beet crop in the Europe, has spread due to irrigation, which can be equated with excess moisture conditions, because *Polymyxa betae* (a soil borne fungus), which is the vector for the beet necrotic yellow vein mosaic virus, prefers wet conditions. On the other hand, *Pleospora betae* causing blackleg was highest under drought conditions. Lane and Jarvis (2007) analyzed that with rising temperatures and change in the rainfall regime the global suitability for crops may not decrease *per se*, but could change geographically. Many instances have been recorded of species range shifts towards the poles or upward in altitude, and progressively earlier seasonal migrations and breeding (Parmesan, 2006). In relation to temperature, for each 1ºC increase there will be a potential for range expansions of ~ 200 km pole ward and similarly, spread of the species ~170 m higher in elevation can be expected. Kiritani (2007) reported on the polar extension of several plant pests in Japan over the period 1965 to 2000. Differential response of wheat leaf rust resistance genes was noticed at different temperatures. Minor or unknown pathogens may also become more aggressive such as alternaria blight of pigeonpea. Meaningful scenarios could be arrived at through a holistic analysis of response of host-pathogen-biocontrol system to the changing climate scenarios. Increasing temperature coupled with increasing moisture will favour the proliferation of Hannukkala *et al* (2007) reported increased and early occurrence of epidemics of late blight of potato in Finland due to climate change and lack of crop rotation.

## Adaptation strategies

The adaptation strategies have to be multi-pronged as the extreme weather events can exert pressure on established plant-pest relationships of a given agro-ecological region. The focus must be laid on understanding host-pest dynamics under different climatic scenarios, deviations in outbreaks of pests, shifts in population dynamics of microflora & fauna, and invasive alien species. The adaptation strategies could be from different angles such as managing nutrient dynamics as well as microbe-mediated management of biotic- and abiotic-stresses. Plant growth is a net result of interaction of roots and shoots with the environment. Both roots and shoots have been shown extensively interacting at rhizosphere, rhizoplane and phyllosphere with microbial communities. Promoting rhizomicroorganisms (PGPR) such as *Rhizobium*, *Frankia*, *Pseudomonas*, *Bacillus*, *Trichoderma*, *Streptomyces* and mycorrhizal fungi have been shown to aggressively colonize roots and help in plant growth and development through nutrient uptake; induction of resistance mechanisms against invading pests; biological control of pests that attack the plants and plant growth promotion.

## Conclusion

In summation, the vast bulk of the available data clearly suggests that atmospheric $CO_2$ enrichment asserts its greatest positive influence on *infected* as opposed to *healthy* plants. Moreover, it would appear that elevated $CO_2$ has the ability to significantly ameliorate the deleterious effects of various stresses imposed upon plants by numerous pathogenic invaders. Consequently, as the atmosphere's $CO_2$ concentration continues its upward climb, earth's vegetation should be increasingly better equipped to successfully deal with pathogenic organisms and the damage they have traditionally done to mankind's crops, as well as to the plants that sustain the rest of the planet's animal life.

# 22. Impacts of Climate Change on Insect Pests


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Unequivocal evidences are available now about the impending impacts of climate change and the consequences thereof. Global Mean Surface Temperature (GMST) and Global atmospheric $CO_2$ concentrations have been increasing at a significant rate since last $19^{th}$ century.

The projected increase in temperature by 2100 was set at by 1.4 - 5.8°C with the increase in the amount of $CO_2$ in the atmosphere by about 40% when compared with pre-industrial levels. The increase in the amount of $CO_2$ in the atmosphere will reach to 500 to 1000 ppm by the end of 21st century (IPCC, 2014). Though climate change is global phenomenon in its occurrence and consequences, it is the developing countries like India that face more adverse consequences. Climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4°C with no substantial change in precipitation quantity. However, different regions are expected to experience differential change in the amount of rainfall that is likely to be received in the coming decades. Last three decades, a sharp rise in all India mean annual temperature was reported (Venkateswarlu, 2009). Climatic variability together with increase in atmospheric carbon dioxide and temperature has lot of implications in agriculture sector influencing significantly the crops and insect pests. Insect herbivores are primary consumers and get energy from plants or plant products and impact of climate change on these insects can have far-reaching consequences and alter significantly. The two dimensions of climate change *viz*., elevated $CO_2$ ($eCO_2$) concentrations and increased temperatures which are cause and effect of climate change influence insect herbivores significantly and relevant information is discussed here under.

## Increased temperature

Climate change resulting in increased temperature could impact crop pest insect populations in several complex ways. Although temperature effects might tend to depress insect populations, most researchers reported that warmer temperatures in temperate climates would result in more types and higher populations of insects. Insects are cold-blooded organisms - the temperature of their bodies is approximately the same as that of the environment. Therefore, temperature is probably the single most important environmental factor influencing their behavior, distribution, development, survival, and reproduction. Increased temperatures accelerate the development of several insect pests resulting in more number of generations (and crop damage) per year. In addition to the above observations some more predictions and generalizations were made by several researchers. The documented information on impact of increased temperature on insect pests indicate the significant migration of insects, accelerated developmental rates and higher oviposition, out breaks, possibilities of introduction of invasive species etc., The effectiveness of insect bio-control by fungi**,** reliability of economic threshold levels, insect diversity in ecosystems, parasitism by parasitoids were found to be varied with increased temperature (Bale *et al.*, 2002). It is well known that increase in the surface temperatures would allow polyvoltine species with accelerated developmental rates allowing the earlier completion of life cycle and thus resulting in additional number of generations within a season. In case of, Aphids (Yamamura and Kiritani, 1998), *Plutella xylostella*, bark beetles *Ips typographus*, *S. litura* and *H. armigera* (Srinivasa Rao *et al.*, 2016) increased number of generations was reported. Insect species diversity per area tends to decrease with higher latitude and altitude, meaning that rising temperatures could result in more insect species attacking more hosts in temperate climates. It is to conclude that the diversity of insect species and the intensity of their feeding have increased historically with increasing temperature.

## Elevated $CO_2$

Generally the impacts of $CO_2$ on insects are found to be indirect through the changes in the host crop i.e., as a result of changes in plant physiology and biochemistry and is mainly referred as host mediated. Elevated $CO_2$ ($eCO_2$) levels generally lead to the accumulation of carbohydrates in the leaf tissue of plants through increased photosynthetic rates, causing an increase in leaf carbon (C) to nitrogen (N) ratio. Since N is considered a limiting nutrient for insects this dilution of N reduces the nutritional quality of the crops. In addition to decreases in leaf N concentration, changes in plant chemical defenses have been documented under $eCO_2$ and these changes could further impact herbivore performance. As herbivores are affected, so are higher trophic levels organisms (secondary consumers) are also get affected. Atmospheric $CO_2$ levels may affect the performance of natural enemies and/or susceptibility of prey directly or indirectly.Insect-host plant interactions will change in response to the effects of $CO_2$ on nutritional quality and secondary metabolites of the host plants. Increased levels of $CO_2$ will enhance plant growth, but may also increase the damage caused by some phytophagous insects. It was observed that in the enriched $CO_2$ condition, the insect confront less nutritious host plants that may extend their larval developmental times. Increased $CO_2$ may also cause a slight decrease in nitrogen-based defenses (e.g., alkaloids) and a slight increase in carbon-based defenses (e.g. tannins).Compensatory feeding is one way by which consumers may be able to mitigate some of negative effects of reduced plant quality under $eCO_2$. Succinctly the information on $CO_2$ impacts showed that the performance of the same insect vary from host to host-indicating host species specificity and the consumption by herbivores was related primarily to changes in nitrogen and carbohydrate levels.

Several experiments were conducted at ICAR-CRIDA using various facilities to study the impact of *e*$CO_2$ levels on insects of rainfed crops .i. Larval duration or time from hatching to pupation in larvae of both the species (*Achaea janata* and *Spodoptera litura*) was significantly influenced by the $CO_2$. Larval duration of both species was extended by about two days when fed with *e*$CO_2$ foliage. Thus, larvae fed with *e*$CO_2$ foliage consumed more each day and over a longer period, resulting in considerably increased ingestion. (Srinivasa Rao *et al*. 2009). ii. Significant influence of *e*$CO_2$ on life history parameters of *S. litura* on groundnut was observed. The per cent variation of these parameters was significant under *e*$CO_2$ compared with ambient $CO_2$. iii. The per cent reduction of nitrogen content and increased per cent of carbon, C: N ratio and TAE (Tannic acid equivalents) was significant in groundnut and castor foliage under *e*$CO_2$. iv. Increased population of aphids, *Aphis craccivora* was increased with reduced generation time on cowpea at *e*$CO_2$. v. *Helicoverpa armigera* larvae consumed higher amount of chickpea foliage resulting increased larval weights under *e*$CO_2$ conditions. These larvae extended their duration by two days.

## Direct and indirect effects of climate change

### Transgenic plants

Currently, Transgenic *Bt* (*Bacillus thuringiensis)* cotton has been adopted to control lepidopteran insect pests and is most notable achievement of biotechnology and addition of proteins from the bacterium (*Bt*) was done successfully. The proteins are nitrogen-based defenses that have a major impact on several common insect pests. Transgenic *Bt* cotton delayed larval – life span, reduced body weight and fecundity, and significantly reduced larval RGR and MRGR. The effects of transgenic *Bt* cotton on the growth and development of cotton bollworm were enhanced when grown under e$CO_2$. Nearly 25% reduction of the expression of these proteins was observed under e$CO_2$. This reduction allowed some lepidopteran larvae (*Helicoverpa armigera* and *Spodoptera litura*) to survive on these plants, which would likely lead to the rapid selection of pest populations resistant to these proteins. The toxic effect of *Bt* in cotton leaves was diluted when plants were grown under *e*$CO_2$ as evidenced by increased larval survival (*H. armigera*) than *Bt* cotton plants grown under ambient $CO_2$.

### Natural enemies

Climate change can have diverse effects on natural enemies of pest species. The fitness of natural enemies can be altered in response to changes in herbivore quality and size induced by temperature and $CO_2$ effects on plants. The susceptibility of herbivores to predation and parasitism could be decreased through the production of additional plant foliage or altered timing of herbivore life cycles in response to plant phenological changes. Impacts of increased $CO_2$ on plant-herbivore interaction may further influence the biological parameters of natural enemies at the third trophic level influencing the growth, development and reproduction, and predation/parasitization preference of natural enemies for herbivorous insects. Differential responses by natural enemies to climate change were reported by several authors. As with temperature, precipitation changes can impact insect pest predators, parasites, and diseases. Fungal pathogens of insects are favored by high humidity. Higher temperatures will favour parasitoids rather than their hosts.

### Invasive pests and distribution

Invasive insect pest species is a non-native species which effects/threatens crop ecosystem or habitat and often these are referred as adventives or non-native species. These invasive pests will effect significantly the crop production and also the food security and buildup their population in the absence of natural enemies with favorable climatic conditions. Warmer conditions in temperate regions may lead to the occurrence of new pest species that were previously restricted by unfavorable conditions, and increase the impact of existing pests. Climate plays a major role in defining the distribution limits of an insect species. With changes in climate, these limits are shifting as species expand into higher latitudes and altitudes and disappear from areas that have become climatically unsuitable. Such shifts are occurring in species whose distributions are limited by temperature such as many temperate and northern species. It is estimated that there would be shift in the crop cultivation due to shifts in the climate change which in turn may cause shifts in incidence of pests. It is observed that a northward shift in the production of rice and maize in the northern hemisphere—major uncertainties remain in the distribution and magnitude of climate change outcomes particularly the pattern of pests. It is well understood that the distribution of insect species is well impacted by the change in climate and unforeseen shifts in species is expected.

## Extremes of Precipitation

Many pest species favour the warm and humid environment. Both direct and indirect effects of moisture stress on crops make them more vulnerable to be damaged by pests, especially in the early stages of plant growth. There are fewer scientific studies on the effect of precipitation on insects. Some insects are sensitive to precipitation and are killed or removed from crops by heavy rains (eg. onion thrips). A decrease in winter rainfall could result in reduced aphid developmental rates as drought- stressed tillering cereals reduce the reproductive capacity of overwintering aphids.

## Summary

It is predicted that global-average surface temperature would increase considerably by 2100 with atmospheric carbon dioxide ($CO_2$) concentrations expected to rise to between 500 to 1000 ppm and with varied rainfall in same period. Two major dimensions of climate change, *e*CO2 and increased temperatures impact crops and insect herbivores significantly.

Elevated $CO_2$ impact the lepidopteran insect pests to go for higher consumption, reduced growth rates, with extended larval duration. Increased temperatures influence insect survival, development, geographic range, no. of generations and population size etc. Significant variation in biochemical constituents of crop foliage i.e., lower leaf nitrogen, higher carbon, higher relative proportion of carbon to nitrogen (C:N) and higher polyphenols were observed in crop foliage grown under $eCO_2$ levels. Climate change impacts the performance of the various lepidopteran and homopteran insect pests both directly and indirectly. Prediction of pest scenarios during future climate change periods indicate that incidence of insect pest is likely to be higher in future.

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# 23. Different Approaches for the Development of Pest Forecasting and Forewarning Models


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Insect pests and diseases are one of the major causes of reduction in crop yield. Timely application of remedial measures may reduce the yield loss. For application of these measures one must have prior knowledge of the time and severity of the outbreak of these pests and diseases. Forecasting system can help in this direction the pest forecasting models facilitate better preparedness to combat outbreaks of serious insect pests by developing effective pest management strategies well in advance.

Different types of approaches can be utilized for developing forewarning system.

## I. Regression Model

The regression model taking pest / disease variable as dependent and suitable independent variables such as weather variables, crop stages, population of natural enemies/predators etc. is used

The form of the model is

$$Y = \boldsymbol{\beta}_0 + \boldsymbol{\beta}_1 X_1 + \boldsymbol{\beta}_2 X_2 + \ldots\ldots\ldots + \boldsymbol{\beta}_p Xp + e$$

where $\boldsymbol{\beta}_0$, $\boldsymbol{\beta}_1$, $\boldsymbol{\beta}_2$,……. βp are regression coefficients, $X_1$, $X_2$, ……, Xp are independent variables e is error term

## II. Growing Degree Day Approach

This method is based on the assumption that the pest becomes inactive below a certain temperature known as base temperature

Growing degree day is worked out as

$$GDD = \boldsymbol{\Sigma}\ (\text{Mean temp.} - \text{Base temp.})$$

- ✓ This method requires proper knowledge of base temperature and initial time from which accumulation is to start
- ✓ Degree-day models are often used to describe the linear development of insects using the accumulation of temperature above the minimum temperature threshold
- ✓ However, due to the non-linearity of the development curve, especially when temperature deviates from the intrinsic optimal temperature of a species, degree-day models are poor predictors of insect development

### III. Principal component regression

- Forewarning models can be developed using the principal component technique as normally relevant weather variables are large in number and are expected to be highly correlated among themselves
- Using the first few principal components of weather variables as independent variables forecast models can be developed

### IV. Discriminant function analysis

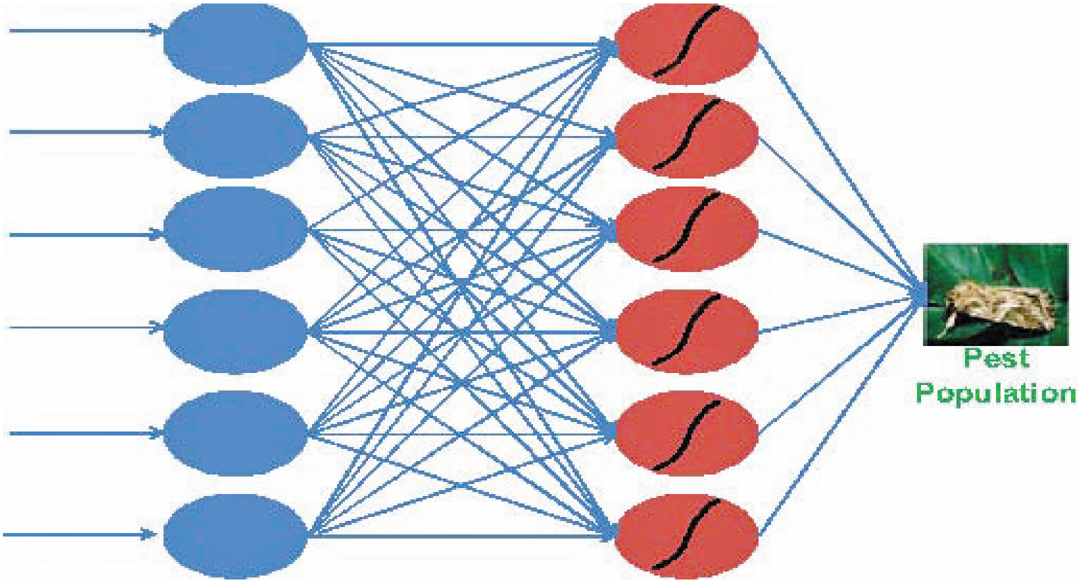
- Forewarning models of pests and diseases based on time series data on weather variables can be developed using the discriminant function analysis
- For this analysis, a series of data for 25-30 years are required
- Based on the pest and diseases variables, data can be divided into different groups – low, medium and high etc. and using weather data in these groups, linear or quadratic discriminant functions can be fitted which can be used to find discriminant scores
- Considering these discriminant scores as independent variables and diseases / pest as a dependent variable, regression analysis can be performed

  Ex:-Discriminant analysis was used for forecasting potato late blight

### V. Artificial Neural Networks (ANNs)

- ANN has received a great deal of attention, because complicated problems can be treated by this even if the data are imprecise and noisy
- Statistical procedures including regression, principal component analysis, density function and statistical image analysis can be given in neural network expressions
- Multilayer perceptron (MLP) was compared with that of linear regression, and it was found that MLP performed better than linear regression
- ANNs can identify and learn correlated patterns between input data sets and corresponding target values through training
- After training, ANNs can be used to predict the outcome of new independent input data and have great capacity in predictive modelling

  Example: Predicting *Spodoptera litura* population in groundnut using Artificial Neural Network (ANN)




Weather variables Hidden layers

*SMW=Standard Meteorological Week

The above described approached have been integrated in many soft-wares and computer-aided tools. Algorithms and tools such as the Maximum Entropy (MaxEnt) and the Genetic Algorithm for Rule-set Prediction (GARP) utilize the inductive approach. Tools such as the Insect Life Cycle Modelling (ILCYM) software utilize the deductive approach. The CLIMEX-compare location function and the North Carolina State University (NCSU) Animal and Plant Health Inspection Service (APHIS) Plant Pest Forecasting System NAPPFAST are based on a combination of inductive and deductive approaches. These tools have been used for development of pest forecasting and forewarning models. Presently at ICAR-CRIDA, Hyderabad research is going on, for the development of forecasting and forewarning models based on the present and future climatic scenarios by using these soft-wares and computer aided tools.

# 24. Climate Smart Practices Implemented in Farmers' Fields

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Warming of the climate system is unequivocal and is more pronounced since the 1950s and several documented evidences exists (IPCC 2014). The atmosphere and oceans have warmed, the amounts of snow and ice have diminished, and sea level has risen. Globally, there are already evidences of negative impacts on yield of important food crops due to increased temperature, water stress and reduction in number of rainy days. In India, significant negative impacts have been projected under medium-term (2020-2039) climate change scenario, e.g., yield reduction by 4.5 to 9%, depending on the magnitude and distribution of warming. Since agriculture currently contributes about 15% of India's Gross Domestic Product (GDP), a negative impact on production implies cost of climate change to roughly range from 0.7 to 1.35% of GDP per year. Enhancing agricultural productivity, therefore, is critical for ensuring food and nutritional security for all, particularly the resource poor, small and marginal farmers who would be the most affected. In the absence of planned adaptation, the consequences of long-term climate change on the livelihood security of the poor could be severe.

Climate Smart Agriculture is an integrative approach to address the interlinked challenges of food security and climate change, that explicitly aims for three objectives: (1) sustainably increasing agricultural productivity to support equitable increases in farm incomes, food security and human development; (2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels, and (3) reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries) to the extent possible (FAO, 2013). Climate resilient agriculture in addition to the above, also consists of elements of preparedness such as documentation of aberrant weather conditions, weather based agro-advisory, awareness about the impacts of weather, etc.

Climate risks are best addressed through increasing adaptive capacity and building resilience which can bring immediate benefits and also can reduce the adverse impacts of climate change and incorporation of adaptation and resilient practices in agriculture which increases the capacity of the system to respond to various climate related disturbances by resisting damage and ensures quick recovery. Such disturbances include events such as drought, flood, heat/cold wave, erratic rainfall pattern, pest outbreaks and other threats caused by changing climate. Resilience is the ability of the system to bounce back and essentially involves judicious and improved management of natural resources, land, water, soil and genetic resources through adoption of best bet practices.

The Technology Demonstration Component (TDC) of National Innovations in Climate Resilient Agriculture (NICRA) is taking up demonstration of climate resilient practices in a big way so as to make communities aware about the resilient practices and to generate awareness and build capacity of farmers and other stakeholders on climate resilient agriculture. TDC is being implemented in 121 vulnerable villages representing climatically vulnerable districts of 28 states and one union territory. The districts selected and their climate vulnerability are depicted in Figure 1. One village or a cluster of villages from each of the 121 selected districts was selected for this purpose by the respective Krishi Vigyan Kendra (KVK- Farm Science Center) in the district. Planning, coordination and monitoring of the program at the national level is the responsibility of CRIDA. Eleven Agricultural Technology Application Research Institute (ATARIs) are involved in coordinating the project in their respective zones. At the district level, the selected KVK is responsible for implementing the project through farmer participatory approach.

The technology demonstration component addresses climatic vulner*abi*lities such as droughts, floods, cyclone, heat wave, high temperature stress, cold wave, frost etc. To address the climate vulnerabilities of the selected village's, technology interventions are planned and prioritization of interventions is based on extent of exposure to climate vulnerability of the different farming situations prevalent in the village and takes into account building resilience of different categories of farmers and communities. Creation of enabling conditions through village level institutional interventions and to promote adoption of climate resilient practices and technologies by farmers to enhance their adaptive capacity and coping ability to climate risks is an important aspect of TDC. Climate resilient practices and technologies implemented can be categorized under four modules: natural resource management, crop production systems, livestock & fisheries production systems and institutional mechanisms.

## Natural Resource Management

Interventions related to *in-situ* moisture conservation, biomass mulching, residue incorporation instead of burning, brown and green manuring, water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, artificial ground water recharge and water saving irrigation methods were demonstrated.

## Crop Production

Introduced drought/temperature tolerant varieties, advancement of planting dates of *rabi* crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through fumigation, staggered community nurseries for delayed monsoon, custom hiring centers for timely completion of farm operations, location specific intercropping systems with high sustainable yield index.

## Livestock and Fisheries

Use of community lands for fodder production during droughts/floods, augmentation of fodder production through improved planting material, improved fodder/feed storage methods, fodder enrichment, prophylaxis, improved shelters for reducing heat stress in livestock, management of fish ponds/tanks during water scarcity and excess water and promotion of livestock component as a climate change adaptation strategy.

## Institutional Interventions

This module consist of institutional interventions either by strengthening the existing ones or initiating new ones relating to community seed bank, fodder bank, commodity groups, custom hiring centre, collective marketing group, introduction of weather index based insurance and climate literacy through a village weather station. The program also aims at development of an enabling mechanism at the village level for continued adoption of such practices in a sustainable manner.

## Impact of Interventions:

Natural resource management interventions such as site specific rainwater harvesting structures in drought affected areas; efficient use of harvested water through supplemental irrigation to alleviate moisture stress during mid-season drought, improved drainage in flood-prone areas, artificial groundwater recharge and efficient irrigation systems were taken up depending on the rainfall, slope and resource endowments of the location. About 760 demonstrations on improved planting methods in several *kharif* and *rabi* crops were carried out during one cropping season. About 594 demonstrations on zero till and DSR cultivation indicated their high potential as a sustainable alternative to conventional planting of wheat, paddy, mustard, maize and vegetable crops. In the hilly and high rainfall north Eastern states, the focus has been on sustainable intensification in rice fallows and zero till sowing, raised and sunken bed planting method for cultivation of grain legumes and vegetable crops. Efficient use of harvested water through micro-irrigation systems to provide critical irrigations to *kharif* crops during dry spells resulted in higher yields and net returns under deficit rainfall conditions in NICRA villages in cotton (Telangana, Gujarat), soybean (Madhya Pradesh and Maharashtra), groundnut (Gujarat), maize (Karnataka) and paddy (Jharkhand, Odisha and Chhattisgarh). Harvested water was used for increasing the cropping intensity by bringing more area under *rabi* crops with increase in yield and returns in several crops such as wheat (Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Rajasthan), mustard (Madhya Pradesh, Rajasthan, Jharkhand), chickpea (Uttar Pradesh, Maharashtra) and vegetable crops (Nagaland, Sikkim, Jharkhand, Bihar, Uttar Pradesh, Himachal Pradesh, Tamil Nadu).

In drought affected districts, soil moisture and nutrient management measures were demonstrated in standing crops experiencing dry spells. Contingency crops such as horsegram, castor, foxtail millet, pearl millet, cluster bean, toria and blackgram were adopted by farmers at different locations. Under the crop production module emphasis was on drought and flood tolerant varieties, timely planting, community nurseries for delayed monsoon, water saving paddy cultivation methods (SRI, aerobic, direct seeding), green manuring, nitrogen management, advancement of planting dates of *rabi* crops in areas with terminal heat stress, frost management in horticulture through fumigation. About 4134 demonstrations were takenup covering 1306 ha area of short duration and drought tolerant varieties across different districts during 2015-16. Resilient intercropping systems in place of sole crops contributed in stabilizing productivity under variable climatic stresses.

Demonstration of location specific fodder production and its storage by silage making addressed fodder needs during the lean season in several districts in Maharashtra, Andhra Pradesh, Gujarat, Karnataka, Himachal Pradesh, Punjab and Bihar. In districts affected by extreme events (high rainfall during November month), timely advisories to minimize damage were issued and demonstrated. About 13,366 soil health cards were distributed to the community in the NICRA villages during the year 2015-16 and emphasis was laid on site and crop specific nutrient management.

The custom hiring centers established as part of the project helped to take up farm operations timely in the villages. Capacity building of farmers is an important activity of the project and about 1568 courses in different thematic areas of climate change were taken up for awareness and capacity building of participating farmers.

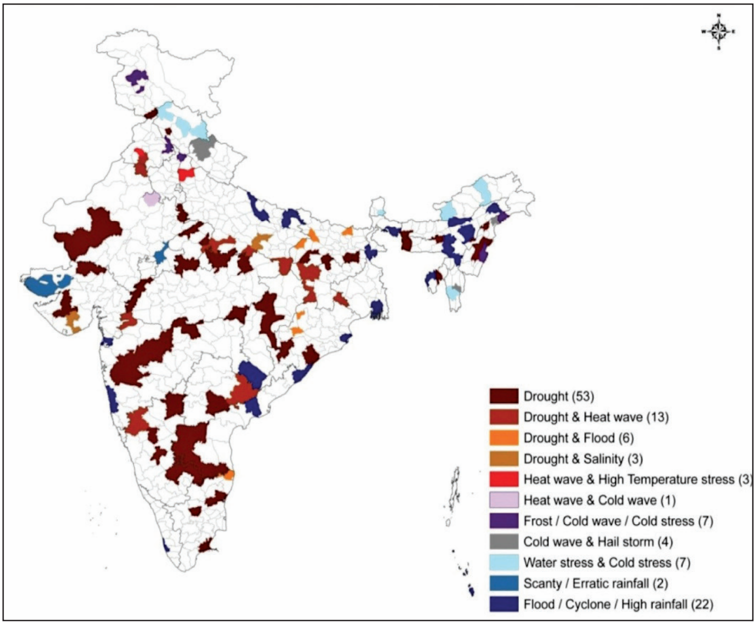


Fig. 1: Map of 121 NICRA-KVK sites, climate vulnerabilities addressed along with number of districts covered

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# 25. Development and Implementation of Agriculture Contingency Plans for Managing Weather Aberrations

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Weather and climate play a key role in agricultural production and influence yields in vulnerable tropical environments. Deficiency in normal rainfall, inappropriate distribution of rainfall within the crop growing season, increased intensity of high rainfall events, increase in minimum temperatures, unseasonal rains are some of the weather aberrations which directly impact the agricultural production in the country and to a large extent in rainfed production systems. The indirect influence of these weather aberrations includes deficient stream flows resulting into insufficient availability of water in reservoirs, decline in groundwater recharge impacting negatively the assured irrigation production systems. In recent past the increased frequency of extreme climatic events caused enormous damage not only to field crops but also to other sectors of agriculture such as horticulture, livestock, poultry and fisheries.

The Indian Council of Agricultural Research (ICAR) through its institutes and state agricultural universities developed relevant technologies to counteract the influences of weather aberrations for various crops and cropping systems. The Federal government to support state governments initiated the process of preparation of a technical document with technologies for each district in the country, which is the primary administrative unit for intervention.

The ICAR along with Ministry of Agriculture and Farmers Welfare made significant efforts to develop the documents so that the district authorities could use them in the need of hour. These documents are titled as 'District Agriculture Contingency Plans (DACP)' and are prepared for all the major weather related aberrations including extreme events *viz.*, droughts, floods, heat wave, cold wave, untimely and high intensity rainfall, frost, hailstorm, pest and disease outbreaks towards preparedness and real time responses covering field and horticulture crops, livestock, poultry and fishery. The district based contingency plans were prepared for 648 out of 651 targeted districts in the country so far and hosted on ICAR / DAC websites (http://farmer.gov.in/, http://agricoop.nic.in/acp.html, http://crida.in/and were made available to all state agriculture departments for implementation.

A standard template was developed in consultation with all stakeholders to cover all prevailing agro-ecological situations in the country towards managing droughts, flood, cyclone and sea water inundation for better preparedness as well as with possible in-season contingencies and suggested adaptive strategies. The template consisting of two parts dealing with (a) district agricultural profile of a district with information on resource endowments such as rainfall, soil types, land use, irrigation sources, more dominant crops and cropping systems along with their sowing windows; livestock, poultry and fisheries information; production and productivity statistics; major contingencies faced by the district and digital soil and rainfall maps and (b) the detailed strategies for weather related contingencies anticipated in crops/cropping systems such as delay in onset of monsoon of different duration; mid-season monsoon breaks resulting in drought both in rainfed and irrigated situations and adaptation strategies for weather related extreme events. These contingency plans contain information on alternate crop varieties/ crops to be chosen in case of delay in onset of monsoon or early season drought and also on agronomic measures for mid and terminal season droughts. Further, strategies for contingency situations in livestock, poultry and fisheries have also been included.

The implementation of DACPs need extensive planning and collective action among many line departments both at centre and state government. The process of implementation essentially consists of two steps (a) preparedness and (b) real time activation of the contingency measures.

The preparedness to address various contingencies include establishment of nodal agencies at various levels, identification, quantification and procurement of inputs (such as seed, nutrients, equipment's etc.) prior to the commencement of monsoon season, protocol development for moving them between stock points to impacted areas within the state etc. The district is considered as a unit for identification and quantification of agriculture inputs while the procurement and stocking is made at the state level.

The ICAR-CRIDA along with Ministry of Agriculture organises interface meetings in various states with stakeholders from all relevant departments including agriculture, horticulture, animal husbandry, rural development and appraises them the weather forecast for the respective state and a consolidated action plan is prepared listing out the interventions to be taken in case of contingency scenario. About 9 such interface meetings were conducted during *Kharif* season of 2019. For the procurement of inputs, particularly seed for alternate crops, the national agencies are involved besides state seed corporations. Preparedness also includes soil and land management treatments such as bunding, broad bed furrows, trenches, addition of tank silt etc. which contribute to conservation of rain water as well as letting out excess water if high intensity rainfall occurs during crop growing season.

The interface meetings at the state were attended by district level officials from agriculture, horticulture, veterinary sciences & rural development and action plans for each district were presented utilising the information available from DACPs and consolidated action plan was made for the entire state.

The activation of agricultural contingency plans began with monitoring of weather in a real time preferably at taluq/mandal (smaller administrative division within the district) level of district along with sowing information on a weekly basis for various crops, identification of areas impacted with long dryspells and crop stages and disseminating information to farmers community on advisories etc. The identified technical interventions along with inputs, if any, are also disseminated to farmers via electronic and print media for making use of them. Based on real time weather and based on protocols developed for initiation of interventions, advisories are issued to farming community. In case of severe drought scenarios, the disaster management department would also be playing a critical role along with agricultural department and necessary inputs such as fodder etc. are brought from other states as well. Animal camps are also arranged by moving the available cattle from various villages to a single place to provide water and fodder during severe droughts.

# 26. Real Time Contingency Plan Implementation: A strategy for Climate Resilient Rainfed Agriculture

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Agricultural production in India is closely linked to the performance of south-west (SW) monsoon (June to September) which contributes about 75% of the annual precipitation. Apart from the SW monsoon rainfall, India receives about 15% of annual precipitation during the winter months of December to March, which is very important for *rabi* (winter) crops. Though rainfall and its distribution have profound influence on Indian agriculture, changes in many components in the climate system including floods, cyclones, heat wave, hailstorms, etc. are also exerting considerable effect. Projected climate change may exacerbate the extreme climatic events and aggravate the risks of drought, flooding, pest infestation, and water scarcity to agro-ecosystems already under great stress (Beddington *et al.*, 2012). Climate change may affect food systems in several ways (Gregory *et al.*, 2005), although not all effects of climate change may be adverse to agronomic/food production (Lal, 2013). The rainfed agriculture is likely to be more vulnerable in view of its high dependency on monsoon and the likelihood of increased extreme weather events due to aberrant behavior of SW monsoon.

## Real time contingency planning

During 1972-73, large scale scarcity of rainfall was experienced all over the country, particularly in the scarcity region of Maharashtra, Karnataka and Andhra Pradesh. Roving seminars were organized by the ICAR at different locations, at the end of which *new phrases* were coined *viz. contingent crop planning and mid-season correction*. As a follow up, the AICRPDA (All India Coordinated Research Project for Dryland Agriculture) centres at Solapur and Bijapur collected data on these two aspects and after analysis of weather data for the past 100 years, listed the weather aberrations: (*i*) delayed onset of monsoon, (*ii*) early withdrawal of monsoon (*iii*) intermittent dry spells of various durations, (*iv*) prolonged dry spells causing changes in the strategy and (*v*) prolonged monsoon (AICRPDA, 1983). Contingency plans, for each region, was a conceptual approach unique from AICRPDA project in developing location specific contingent crop strategies which were first published in 1977 (Ravindra Chary *et al.*, 2012) and with further refinements and updating in crops and varieties, the first document was brought out by AICRPDA in 1983 on "Contingent crop production strategy in rainfed areas under different weather conditions" (Venkateswarlu *et al.*, 1983). The AICRPDA network centers developed crop contingency plans for each centre's domain (Subba Reddy *et al.*, 2008; Ravindra Chary *et al.*, 2012). Further, during 2009-10, AICRPDA centres prepared contingency measures considering weather aberrations, seasons, and the predominant *kharif* (June-September) and *rabi* (winter) crops with appropriate crop management strategies.

It is evident that the rainfed agriculture is being highly impacted due to frequent weather aberrations such as delayed onset of monsoon and/or in-season drought during crop growing period in one or the other part of the country. Therefore, to minimize the crop production and productivity losses and to improve the efficiency of the rainfed production systems, Real Time Contingency Planning (RTCP) was conceptualized in All India Coordinated Research Project for Dryland Agriculture (AICRPDA). RTCP is considered as "any contingency measure, either technology related (land, soil, water, crop) or institutional and policy based, which is implemented based on real time weather pattern (including extreme events) in any crop growing season" (Srinivasarao *et al*., 2013). The major objectives of RTCP are to (i) establish a crop with optimum plant population during the delayed onset of monsoon; (ii) ensure better performance of crops during seasonal drought (early/mid and terminal drought) and extreme events; (iii) enhance performance, improve productivity and income; and (iv) enhance the adaptive capacity and livelihoods of the farmers.

## AICRPDA-NICRA programme: Implementation and experiences

The All India Coordinated Research Project for Dryland Agriculture (AICRPDA) was launched in 1970 by ICAR in IV Plan period, in collaboration with the Government of Canada through Canadian International Development Agency (CIDA) with Coordinating Cell at Hyderabad, Andhra Pradesh. Presently, AICPRDA network has 19 main, 3 sub and 9 voluntary centers located in 18 states representing diverse rainfed agro-ecologies. The 23 Network centres of AICRPDA were included in the National Innovations in Climate Resilient Agriculture (NICRA) Project for taking up demonstration and research activities at various centres in a network mode. The demonstration component of NICRA was finalized in these centres in a participatory mode. Further, the network programme envisaged identifying climatic vulne*rabi*lities of agriculture in the selected villages by each centre based on historical weather data from the nearest weather station, farmers' experiences and perceptions, preparing and implementing adaptation and mitigation strategies following a bottom-up approach. The focus of the program is not only to demonstrate the climate resilient agriculture technologies but also to institutional mechanisms at the village level for implementation of successful adaptation strategies on a sustainable basis. The AICRPDA-NICRA programme was implemented, both on-station and on-farm, with a focus on managing weather aberrations through Real-Time Contingency Planning (RTCP) concept and as two pronged approach i.e. real-time implementation and preparedness. During 2011-17, RTCP was implemented in 34 adopted villages in 15 states. In 2017, the on-farm programme as

Cluster approach was extended to 55 adopted villages (23 clusters) in 15 states.

During 2011 to 2018, under delayed onset of monsoon conditions, short duration and drought tolerant varieties of major rainfed crops were assessed for their suitability and best performing varieties were identified for different agro-ecologies. On an average, these varieties gave about 15-35% higher yields and net returns compared to local/farmers' varieties. Early season drought conditions were addressed through *in-situ* moisture conservation and mulching which helped in adaptation of crops and realizing improved yields by 16-31% compared to no contingency measures (farmers' practices). RTCP measures through foliar sprays of thiourea and $KNO_3$ in mitigating midseason drought/dry spells gave 10-20% higher yield in different crops compared to no spray. The effect of terminal drought on different crops was mitigated mostly by providing supplemental irrigation from harvested rainwater in ponds, and foliar sprays. Supplemental irrigation improved yields by 25% in cotton, 40% in groundnut and 55% in soybean at different locations. Similarly, foliar spray of 1% KCl in rice during dry spell at flowering-milking stage increased yield by 25% compared to no spray and foliar spray of water soluble NPKS complex fertilizer (18:18:18:6) @ 0.5% + $ZnSO_4$ @ 0.5% increased maize grain yield (2961 kg/ha) by 36% compared to water spray (2192 kg/ha) (AICRPDA-NICRA, 2018).


Fingermillet var. A-404 under delayed onset of monsoon


Opening of conservation furrows for *in-situ* moisture conservation in groundnut + pigeonpea intercropping system


Protective irrigation using sprinklers in groundnut

The experiences of AICRPDA indicated that to strengthen RTCP implementation on wider scale there is a need for: i) production and availability of seed of contingent crops/varieties through public and private sector agencies/programmes, establishment of community/village seed banks, ii) promotion of model custom hiring centres for supply, repair and maintenance of suitable, energy efficient and cost-effective farm implements/machinery particularly for sowing, iii) rainwater management interventions are capital and labour intensive, hence need to be converged with state/national programmes/schemes, iv) timely procurement and supply of suitable foliar spray chemicals, v) efficient recycling of farm residues for mulching, vi), weather and climate information systems to provide forecasts, vii) convergence with government schemes, viii) policy interventions, and x) strong preparedness for particular foreseen weather aberration (based on long term experiences or trends) along with actually responding to the situation in a needed way, so that negative impacts of such weather events could be minimized.

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# 27. Farm Machinery Custom Hiring Centres: Tool to Combat with Climate Change Impact

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Climate change poses serious threats to food security mission in India. There are several changes has been occurred like temperature rise, cyclones, heat wave, cold wave, frost and hail storm over short periods, changed rainfall pattern which are significantly affecting on of agricultural production system. So, enhancing the farmer's income is the really challenging task particularly in rainfed. But it is observed that it can be achieve by integrated approach with all aspects of agriculture. Farm mechanization is one of the major aspect that gives timeliness operation, cost saving, quality operation, comfort, etc. Timeliness operation reduces weather risks by enabling the farmers to diversify the operation with greater efficiency and decrease the risk of non-availability of labour and thus wastages are minimized (Bhardwaj, 2014; Sassenrath, 2008). These are the important factors that favor mechanization. But for small farmer it not possible to purchase required machinery to mechanized his field operation. Therefore, establishing Custom Hiring Centres (CHCs) with expensive and most demanded farm implements in villages is an important strategy to meet machinery needs of farmers particularly from small and marginal sections. CRIDA has established more than 151 Custom Hiring Centers of farm implements across all ecological regions in India under National Innovations in Climate Resilient Agriculture project (NICRA), an ICAR Flagship Platform. Apart from that, many of the State Government Agencies, NGOs and other entrepreneurs have established and are operating these Custom Hiring Centers in various parts of the country. A positive impact is seen across the country on these CHCs established by different organizations. However, still there are operational and technical constraints involved in establishing these centres. This paper provides the information about successful establishment and operationalization of CHC specific advantages observed in terms of coping with the climate variability as well as major constraints in management of CHC.

## Major factors to be considered for establishment of Custom Hiring Centres

1. Identification of major crops in the nearby villages: Cropping pattern in a cluster of villages plays a vital role in selection of farm implements. Sometimes, farmers change the cropping pattern based on the market demand. Hence, data on cultivated area under major crops is essential to understand the different types and numbers of farm implements required.

2. Type of soil in the cropping area: Soil type decides the tillage, sowing and weeding equipment efficiency. Lots of soil variation is observed throughout the country. Hence, type of soil in nearby area is to be taken in to view for finalizing the equipment.

3. Identifying the critical farming operations: Some of the farming operations need more mechanical interventions than the other operations. Priority should be given to mechanize the major operations.

4. Preliminary survey on socio-economic status: Social and economic status of majority of the farmers is to be taken in to view before establishment of the centre. Sometimes social problems may create negative impact to open the centre. Poor economic situation of the farmers needs government support to pay the minimum rental charges.

5. Identification of suitable farm equipment for different operations: This is a major challenge of the total system. The performance of equipment will vary based on the crop and type of soil. Availability of cheapest power source is to be taken in to consideration. The land environmental factors are also to be considered to assess the wear and tear of equipment.

6. Financial support from the loaning agencies: The establishment of centre needs moderate funding support from the financial institutes for running the centre profitably. We need to keep adequate number of each equipment to cater the needs of cultivable area in time. Hence, the operator should have enough financial strength for mobilizing the initial and running investment.

7. Availability of trained man power: Centre needs trained technical man power for smooth running. Farmers at time demand quality service in a very short span of time to meet the timeliness of the operations. Thus, any delay in repairing will affect the customer heavily.

8. Location of minor repairing industries nearby: Very often the equipment needs timely repair. Therefore, small scale engineering workshops should be available within short range for smooth operation of the centre.

9. Fixations of hiring charges: This plays a key role in successful running of the centre. If the charges are high, the owner may get initial profits but the competition from local independent single piece equipment operators will be more. Hence, low rental charges that supports centre, depreciation of equipment and interest on finance is always better for the sustainability of the centre.

10. Updating the centre with new models: Latest equipments should be made available in custom hiring centre within short time. Otherwise some of the individual owners may introduce and reach to the farmers which may directly affect the profit of centre.

11. Equipment shed: Enough space should be available for easy movement of the tractor to load and unload the equipment to meet the time factor. No implement should be kept in open area.

12. Size and capacity of the machinery: Based on the size of the land holdings, size of the machinery also varies. However, medium size equipments will always work well in small and big land holdings.

Fig. 1: Establishment of CHC under NICRA

## Training to Field Staff and Farmers:

Necessary trainings on skill development for operation and maintenance of the machinery are imparted to the resource persons and farmers at CRIDA and at CHC centres.

Fig. 2: Training to the field staff

## General Constraints in CHCs operation

Following constraints was observed during review of NICRA CHCs

1. Repair and maintenance cost of the equipment like rotavator, thresher, shredder was not being met through the generated revenue.

2. Lack of permanent skilled person to look after the CHCs work and maintenance.
3. Farmers did not take the responsibility of repairing equipments. At times, there was great delay from farmer's side in returning the equipment.
4. Payments were not regular.
5. High demand for certain implements during peak season.
6. Under utilization of certain equipments like reaper, power weeders etc. during off season.
7. Demand for costly equipments like combine harvesters, boom sprayers, threshers etc.
8. Differences among the farming community on priority use of implements.

## Benefits of Custom Hiring Centres

1. It makes available various farm machinery / equipments to small and marginal farmers at affordable rent on hiring basis,
2. It helps to meet timeliness of operational needs through appropriate machinery
3. It facilitate farmers on application of innovative crop management practices with specific machinery
4. Increases the productivity and cropping intensity by increasing the power availability at farm level.

Fig. 3: Feedback from Farmers

## Specific advantages observed in terms of coping with the climate variability:

1. Mechanization in critical operations improved with access to appropriate machinery.
2. Zero tillage machines of CHCs impacted on crop productivity (wheat, maize, rice) because of timely sowing and energy and water saving.

3. Crop residue burning was reduced with the introduction of rotavator, mobile chipper shredder and recycled back into the soil for improving soil organic carbon and soil health.
4. Timely harvesting and threshing in unforeseen climatic conditions.
5. Cropping intensity had also increased in some of the areas because of timely planting, inter-culture & harvesting operations.
6. Some of the critical agronomic recommendations like intercropping and residue incorporation, paired up with row planting are taken up in time with the help of advanced machineries like multi crop planters and mobile shredders, raised bed planter etc.
7. Overall profit by 20 to 30% in addition to input savings of 25-30%.

## Evaluation of Farm machinery Custom Hiring Centers

After establishing the CHCs, the high level monitoring committee constituted for NICRA project recommended CRIDA to evaluate the performances of CHCs. Accordingly, scientists of CRIDA and Central Institute of Agricultural Engineering selected 22 Krishi vignan kendras (KVKs) for their performance evaluation in terms of viability, sustainability, economics, status of working and other social factors.

## Conclusions

Due to climate change, field working days were affected mostly in rainfed agriculture. Sowing, weeding and harvesting windows are becomes short due to variation in rainfall. Therefore establishment of CHC and selection of implement according to the requirement of farmers is very important. It is an important strategy for successfully implementation of adoption and mitigations to deal with climate change. Timely sowing, weeding, intercultural, threshing and harvesting operation were established components in dealing with weather abbreviations like late on-set of monsoon, drought, intermittent drought, floods, cyclone, water logging and frost etc. Custom hiring centres established in 100 villages/districts have provided many opportunities in dealing various weather duration during 2011 and 2012. In depth, analysis of these constraints will be essential for strengthening Custom Hiring Centre (CHCs).

# 28. Adaptive Management of Small Ruminants to Climate Change and Fodder Production Systems

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Climate change has been, and continues to be the most important cause of instability in ruminant production systems in tropical countries like India through crop failures, fodder scarcity and increased incidence of endemic animal diseases. Alterations in rainfall affect the fresh water availability for feed production and also drinking water for livestock. Further, scenario of feed and fodder resources and demand in the country explicitly indicates the necessity of efficient utilization of available resources from crop and cropping systems and development of integrated silvi/horti-pastoral systems for sustainability of not only farmer's income but also the productivity of livestock. Hence, one should be critical in recommending adaptive livestock management practices in view of much diversified and heterogeneous group of farmers and the resources accessible to them.

## Impact of climate change on small ruminant production systems:

Dry matter intake decreases especially young and productive animals exposed to heat stress. In addition, there can also be a decrease in the efficiency of nutrient utilization and increased loss of sodium and potassium electrolytes. Sudden changes in temperature, either a rise in T max (>4°C above normal) during summer i.e. heat wave or a fall in T min (<3°C than normal) during winter i.e. cold wave cause mortality and morbidity in small ruminants. A rise temperature due to global warming projected to negatively impact growth, puberty and maturity small ruminants. The main effects include decrease in the length and intensity of the oestrus period, decreased fertility rate, decreased growth, size and development of ovarian follicles, increased risk of early embryonic deaths and decreased fetal growth and lamb/kid birth weight.

Besides the direct effects of climate change on animal production, there are profound indirect effects as well, which include climatic influences on quantity and quality of feed and fodder resources such as pastures, forages, grain and crop residues and the severity and distribution of livestock diseases and parasites. Rising temperatures increase lignifications of plant tissues and thus reduce the digestibility and the rates of degradation of plant species. Rainfed areas which receive relatively low rainfall are expected much reduction in herbage yields especially in dry seasons. Temperature and humidity variations could have a significant effect on helminthes infections also. Thus, in general, climate change-related aberrations will have adverse impacts on animal health and production systems.

## Adaptation strategies for optimum production from small ruminants:

Adaptation helps in reducing vulnerability of small ruminants and ecosystems to climatic changes. Small ruminant keepers, especially resource poor land less farmers (shepherds) have a key role to play in promoting and sustaining a low-carbon rural path through good management practices. It is important to remember that the capacity of local communities to adapt to climate change will also depend on their socio-economic and environmental conditions, and on the resources available and extent of accessibility for the resources.

## Adaptation strategies:

Adaptation strategies augment tolerance of small ruminant production systems and enhances ability to survive, grow and reproduce in conditions of deprived nutrition, high incidence of parasites and diseases under extreme weather events. There is no one-size-fits-all solution for adaptation, measures need to be tailored to specific contexts, such as different breeds of animals, production level, ecological and socioeconomic patterns, and to geographical location and traditional practices. The foremost adaptation strategy that help in reducing the vulnerability of small ruminant production systems include enhancing feed and fodder base both at household and community level. This can be achieved by mapping of ecologically sensitive pastures and development of rehabilitation packages, rehabilitation and productivity enhancement of degraded grazing lands, promoting fodder species under agro-forestry initiatives, developing seed/ germplasm banks/ nurseries of native species for rehabilitation of grazing lands, developing fodder storage/ value addition facilities, capacity building of Managers/ Community Groups along with intensive irrigated fodder production systems with high yielding perennial (hybrid Napier varieties like CO-3, CO-4, APBN-1 etc.,) and multicut fodders varieties (MP Chari, SSG etc.,), intensive rainfed fodder production systems by growing two or more annual fodder crops as sole crops in mixed strands of legume (Stylo or cow pea or hedge Lucerne etc) and cereal fodder crops like sorghum, ragi in rainy season followed by berseem or Lucerne etc., in *rabi* season, short duration fodder production from tank beds with sorghum and maize fodder, sowing *Stylo hamata* and *Cenchrus ciliaris* in the inter spaces between the tree rows in orchards or plantations as hortipastoral and silvopastoral integrated fodder production systems, fodder production systems through alley cropping, perennial non-conventional fodder production systems with deep rooted top feed fodder trees and bushes such as *Prosopis cineraria, Hardwickia binata, Albizia* species, *Zizyphus numularia, Colospermum mopane, Leucaena leucocephala, Azadirachta indica, Ailanthus excelsa, Acacia nilotica* etc., use of unconventional resources form food industries like palm press fibre, fruit pulp waste, vegetable waste, brewers' grain waste and all the cakes after expelling oil as feed. Further, fodder production at homesteads through Azolla, hydroponic Fodder Production with barley, oats, lucerne and rye grass, year-round forage production with suitable perennial and annual forages like growing annual leguminous fodders like cowpea or horse gram etc inter-planted with perennial fodders like Co-3, CO-4, APBN-1 varieties of hybrid Napier in *Kharif* and intercropping of the grasses with berseem, Lucerne, etc., during *rabi* season would also increases resilience of livestock production systems through continuous supply of nutritious fodder.

Substantial fodder can be produced through prior contingency planning. During early season drought, **s**hort to medium duration cultivated fodder crops like sorghum (Pusa Chari Hybrid-106 (HC-106), CSH 14, CSH 23 (SPH-1290), CSV 17 etc) or Bajra (CO 8, TNSC 1, APFB 2, Avika Bajra Chari (AVKB 19)etc.,) or Maize (African tall, APFM 8 etc.,) which are ready for cutting in 50-60 days and can be sown immediately after rains under rainfed conditions in arable lands during *Kharif* season results in optimum fodder production. If a normal rain takes place in later part of the year, *rabi* crops like Berseem (Wardan, UPB 110, etc varieties), Lucerne (CO-1, LLC 3, RL 88, etc.) can be grown as second crop with the available moisture during winter. In waste lands fodder varieties like Bundel Anjan 3, CO1 (Neela Kalu Kattai), *Stylosanthes scabra,* etc. can be sown for fodder production. In case of mid season drought, suitable fodder crops of short to long duration may be sown in *Kharif* under rainfed conditions. Mid season drought affects the growth of the fodder crop. Once rains are received in later part of the season the crop revives and immediate fertilization help in speedy recovery. If sufficient moisture is available, *rabi* crops like Berseem (Wardan, UPB 110, etc. varieties), Lucerne (CO 1, LLC 3, RL 88, etc.) can be grown during winter. In waste lands fodder varieties like Bundel Anjan 3, CO-1 (Neela Kalu Kattai), Stylosanthes scabra etc., can be sown for fodder production. As late season drought affects seed setting, normal short duration fodder crops may be sown. Avoid multicut fodder varieties under rainfed conditions. All the available fodder must be harvested before drying out to preserve nutritive quality. Depending on availability of moisture, *rabi* fodder crops especially low water requiring varieties of lucerne may be planted. In wastelands, grasses like Cenchrus ciliaris, C. setigerus, Chloris gayana, Panicum maximum, Desmanthus virgatus, Stylosanthes scabra can be taken up to increase forage production. In areas that receive north east monsoon rains, multi-cut fodder varieties of sorghum (CO 27, Pant Chari-5 (UPFS- 32), COFS- 29 or pearl millet (Co-8) or maize (African tall) are recommended. In areas that receive summer rains, fodder crops like cowpea and maize are best suited.

The second most important in building the resilience small ruminant production systems is development and promotion of integrated farming systems. Integrated farming system besides generating higher productivity, it also produces sufficient food, fruits, vegetables etc., to the farm families. Several IFS models like (A) Conventional cropping; (B) crop + poultry (20) + goat (4); (C) crop + poultry (20) + goat (4) + dairy (1); (D) crop + poultry (20) + goat

(4) + sheep (6); and (E) crop + poultry (20) + goat (4) + sheep (6) + dairy (1) were studied. Among the models examined, model (E) recorded a maximum net income of Rs 52794/ha, with maximum employment generation (389 man days/ha/year) (Solaiappan *et al*., 2007). These types of systems are suitable for the scarce rainfall zone.

Crop- small ruminants- poultry - fishery integrated farming system are mostly suitable for high rainfall areas, where paddy is cultivated both in *Kharif* and *Rabi* seasons. Sheep/goat are maintained at backyard with crop residues and supplements. Fish is reared in farm ponds and poultry is maintained in cages over the pond with grain and bran supplementation. The droppings of poultry serve as feed for the fish in the pond.

Silvi-pastoral systems are efficient integrated land use management systems of agricultural crops, tree fodder species and or livestock simultaneously on the same unit of land which results in an increase of overall production. Inter spaces between fodder trees species (*Leucaena leucocephala*) are utilized for cultivation of grasses and grass legume mixtures (*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra*), which provides a two tier grazing under *in-situ*. This type of systems provide Rs.25000-30000 income per ha (Ramana, *et al*., 2000) and helps in reclamation of soil in waste lands and are more suitable for rearing small ruminants (10-12 animals/ha) in degraded waste lands under dryland conditions in Scarce rainfall zone. Horti-pastoral systems, the inter tree spaces in the mango/lemon/sweet orange orchards are utilized for cultivation of grasses and grass legume mixtures (*Cenchrus ciliaris* and *Stylosanthes hamata* or *scabra*) along with one side boundary plantation of fodder trees species (*Leucaena leucocephala*). Cultivated fodder and weeds serve as feed for the animals. Integration of lambs provide Rs. 4000-5000 additional income per ha through sale of animals, control weeds by grazing/browsing and also improve soil fertility through faeces and urine (Ramana, 2008 and Ramana *et al*., 2011).

Further, modifications in feeding, breeding and shelter management would enhance resilience of small ruminant based production systems. This includes, (i) modifying grazing practices (rotational grazing and or restricted grazing); (ii) introducing especially during lean period, such as stall-fed systems through cut and carry fodder production; (iii) better feeding management through conventional and unconventional feed resources (iv) providing proper shelter and adequate wholesome water throughout the year (v) identification and promotion of local high productive resilient breeds that have adapted to local climatic stress and feed sources; (vi) improvement of local animals through cross-breeding with heat and disease tolerant breeds and (vii) synchronization of oestrus based on the availability of feed resources and favourable climatic conditions, (viii) supplementation of micro minerals and vitamins especially during lean season, (ix) Eradication, containment and surveillance of endemic animal diseases.

## Conclusions

Enhancing the fodder supply, integrated production systems, value addition, information and knowledge sharing through agro and animal advisories, crop cum small ruminants insurance, conservation and promotion of highly productive native breeds, contingent fodder-animal planning, scaling-up of proven resilient production systems to spread the adaptation options and innovations to a wider community with capacity building of small holders would certainly build the resilience of small ruminant production systems.

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# 29. Ensuring Fodder Availability in Rainfed Areas Under Climate Change Scenario in India

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Livestock sector has played a significant role in the overall growth of rainfed agriculture in general and agriculture sector in particular. About 4.11% of gross domestic product of the country and 25.6% of agricultural GDP comes from livestock. One of the factors limiting the growth of the livestock sector is the availability of feed and fodder. It has been estimated that there is deficient of 23 and 32% in the availability of dry and green fodder, respectively. To meet out the deficit, green forage supply has to grow at 1.69% annually (IGFRI, 2013). Rainfed areas constitute 55% of the net sown area of the country and are home to two third of the livestock. In India where over 75% farmers are small and marginal holders and livestock remain the main source of livelihood for a majority. The demand for milk and meat in India is creating new potential in the profitability of animal husbandry as an occupation. Yet, at the same time, there is a substantial decline in fodder availability. There are many constraints for fodder production in the country. Declining area under grazing land, lack of suitable varieties or fodder crops and soil constraints are those listed from long ago. However, increasing climate variability is gaining prominence recently. A warmer climate with increasing climate variability will increase the risk of climate extremes (Whetherald and Manabe, 2002). Climate change is likely affect fodder production and nutritional security of livestock. Under elevated $CO_2$, fodder plants and residues of crops, which are main source of fodder from several crops, will have high C: N ratio, and this may greatly reduce their nutritive values when used as fodder. High ligin in deposition at high temperature may also severely affects quality of fodder. The approaches and technologies for addressing the fodder shortage and to improve feed and fodder availability particularly in rainfed areas are discussed:

## Improved crops/varieties

Short and medium duration fodder cultivars of several crops that can withstand up to 2-3 weeks of exposure to drought in rainfed areas were demonstrated in NICRA villages. These include: sorghum (Pusa Chari Hybrid-106 (HC-106), CSH 14, CSH 23 (SPH-1290), CSV 17); Bajra (CO 8, TNSC 1, APFB 2, Avika Bajra Chari (AVKB 19); Maize (African tall, APFM 8). These cultivars can be sown immediately after the rains under rainfed conditions in arable lands during *Kharif* season and are ready for cutting by 50-60 days. Cultivars of *rabi* crops like Berseem (Wardan, UPB 110) and Lucerne (CO 1, LLC 3, RL 88) were demonstrated in NICRA villages as second crop with the available moisture during winter. Perennial fodders like APBN-1, CO-3 and CO-4 were also demonstrated under limited irrigated (Prasad *et al.,* 2014)

## Making utilization of available residues

Crop residues can be a best option to share a good percentage of fodder needs in rainfed area provided they are well processed and stored to increase the quality. Sorghum maize and millets are the major crops grown in rainfed areas that are well suited for fodder needs. Not realizing the potential, majority of the farmers are wasting the crop residues either by burning it or feeding the stalks directly. Timely harvesting of crop residues, proper processing and storage can also enhance the quality of the forage and prevent wastage. Harvesting of stalk before it turns fibrous for direct feeding or converting into silage, can keep the nutritive value high while reducing methane generation by the ruminants. There are various methods of treating the crop residues before feeding, to improve its nutritional value. Excess of stalk can be very well processed and converted into silage for use during lean months. Further treatment of crop residues by way of soaking in water and treating with steam under pressure, can also improve the nutritive value and palatability.

## Community fodder bank

A community fodder bank is nothing but, a group of farmers coming together to raise multiple fodder crops consisting of trees, grasses and legumes, largely in non-arable or wastelands in order to meet the fodder requirement especially during lean periods. The idea of fodder banks emerged with the aim of replenishing arable lands that have lost their fertility due to continuous cropping. Thus, a fallow land is sown to leguminous perennial forages or self-seeding perennials so as to rebuild the nitrogen content of the soil through biological nitrogen fixation, and at the same time, for production of high quality dry fodder. The system is like a forage/crop rotation except that the forage phase may last for three or more years until the desired fertility level of the soil is attained. Planting of high biomass yielding and fast-growing grasses and shrubs suitable for fodder in these areas not only increases fodder availability, but also reduces soil erosion. These fodder banks also help in the preservation and storage of surplus fodder, availability of nutritious fodder during the period of fodder scarcity and enhance nutritive value of crop residue.

## Fodder development programme

Department of Agriculture and Cooperation (DAC) has come up with a new multi-prolonged strategy called “Accelerated fodder development program” (AFDP) in the year 2011 which includes:

**Production of Quality Seeds:** Supporting/Strengthening State Agricultural Universities for production of breeder and foundation seeds of selected promising varieties/hybrids of fodder with participation of farmers.

**Production of Fodder:** Organizing fodder production programme based on cluster approach in the selected/targeted clusters preferably in dairy catchment areas of the potential states by promoting appropriate and region-specific fodder varieties.

**Adoption of appropriate technologies for Post Harvest Management:** Technologies like fodder block making units, chaff cutter for fodder processing and silage making would be promoted in the selected/targeted clusters.

The AFDP will be implemented as a sub-scheme of *Rashtriyav Krishi VikasYojana* (RKVY). Besides, improving productivity in areas already under fodder cultivation, improving productivity of grazing and pasture lands, raising perennial fodder crops on field bunds and boundaries, peri-urban areas and exploiting unutilized and under-utilized fodder crops are also some of the promising options to enhance fodder availability. The National Agro-forestry Policy (2014) also has a basic objective of supplementing the availability of agro-forestry products (AFPs) including fodder.

National Livestock Mission (NLM) is a recent program launched by Ministry of Agriculture in year 2014-15 to ensure quantitative and qualitative improvement in livestock production systems. One of the sub mission under this program is "**Feed and Fodder Development"** which is designed to address the problems of scarcity of animal feed and fodder resources, to give a push to the livestock sector making it a competitive enterprise for India, and also to harness its export potential. The program will focus on increasing both production and productivity of fodder and feed through adoption of improved and appropriate technologies best suited to specific agro-climatic region in both arable and non-arable areas. The important components targeted by this program include:

### Fodder production from Non-forest wasteland /rangeland/ grassland / non- arable land

- Rehabilitation of degraded Non-forest wasteland / rangeland / grassland / non-arable land by introducing suitable grass, legumes and fodder trees
- Increasing production of palatable grasses / legumes / tree leaves
- Production of bio-mass to minimize the gap between availability and requirement of fodder
- Creating surplus reserve of forage for use during lean periods / crisis situations

### Fodder production from Forest land

- Rehabilitation of degraded Forest land by introducing suitable grass, legumes and fodder trees
- Increasing production of palatable grasses / legumes / tree leaves, along with improving the forest floor

- Production of bio-mass to minimize the gap between availability and requirement of fodder
- Creating surplus reserve of forage for use during lean periods / crisis situations Fodder seed production / procurement and distribution
- Promoting cultivation of superior variety of fodder crops for fodder seeds (breeder, foundation and certified seed), preferably through contract farming, with a buy back arrangement, and distribution of seeds among the farmers.

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# 30. Tillering Maize as Resilient Grain, Feed and Fodder Crop

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Maize (*Zea mays* L.) is one of the most important cereal crops in the world, being among the primary sources of human food, animal feed, and raw material for some industrial processes. Maize has wider adaptability under varied agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. Wild species are important sources of genetic variability and may be exploited by breeding programs to introgress desirable traits. The potential use of Teosinte in maize breeding has been evaluated since 1950s. Researchers concluded that Teosinte is a valuable germplasm for maize improvement, providing resistance to diseases and other abiotic stresses, as well as quantitative traits.

Maize genotypes with 1 to 5 tillers are being developed at CRIDA. The maize germplasm for unique characteristics *viz*., 1) one-five tillers/plant, 2) Tillers with effective cobs and 3) Cobs with effective seeds for fodder and food are being developed at CRIDA. Natural mutant with tillers was first identified in Hayathnagar Research Farm of Central Research Institute for Dryland Agriculture, Hyderabad. This tillering mutant with ineffective tillers, cob and seed was crossed with Teosinte/ African tall/ normal maize for increasing the tiller height, effective tillers with normal cob and seed size. Various methods of breeding include recurrent selection, back cross breeding, half sib, full sib followed by pedigree breeding method.

Plants with single tiller (main stem and single tiller) recorded cob weight of 250-290g/plant and total biomass of 600-650 g/plant.

Plants with two tillers (main stem and two tillers) recorded cob weight of 260-300g/plant and total dry biomass of 750-800 g/plant.

Plants with three to five tillers recorded cob weight of 300 -375g/plant and total dry biomass of 800-950g/plant.

Tillering maize with 1-2 tillers can be used as multi-purpose crop to meet the feed demand from poultry industry, as human food for grain and the demand for good quality stover to feed cattle.

While tillering maize with 3-5 tillers can be used for fodder purpose as these plants have more of dry biomass.

Fig. 1: Field view of tillering maize

Fig. 2: Tillering maize plants with 1-5 tillers

# 31. Vulnerability and Vulnerability Assessment: Concepts and Methods


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The last decade of the 20th century saw two important developments: the establishment of United Nations Framework Convention on Climate Change in 1992 and the commencement of the World Trade Organization in 1995. Both these 'events' have significant implications to the way the nations pursue their development goals, especially the developing countries. Various agencies involved in and concerned with economic development have these two aspects on their activity agenda and the researchers are no exception. An important area of research that received attention from different backgrounds is related to vulnerability and its assessment. The term 'vulnerability' has been used in many different contexts and with different meanings and often without even defining the word. Timmermann (1981) observed that "vulnerability is a term of such broad use as to be almost useless for careful description at the present, except as a rhetorical indicator of areas of greatest concern". The term is often used synonymously with susceptibility, fragility, resilience, adaptability, coping capacity, sensitivity, etc. It is important to have a clear understanding of the concept and meaning of vulnerability and its assessment given its importance in the context of climate change and agriculture.

## Vulnerability – meaning and concepts

'Vulnerability' has emerged as a cross-cutting multidisciplinary theme of research in the current context, characterized by rapid changes in environmental, economic and social systems (O'Brien *et al.,* 2004). The word vulnerability has been used and vulnerability was assessed without actually being defined in many different contexts. Vulnerability is an *ex ante* concept in that what is likely to happen in future is the focus of analysis and thus the analysis has to lead to making decisions as to what is to be done in the present. Further, vulnerability of what to what are to be clearly defined along with the preference criteria for evaluation (Ionescu *et al.,* 2009).

- **Connotations of vulnerability:** Vulnerability and its assessment received attention in three important areas of research: disaster management, economic development and climate change. The disaster management literature sees vulnerability as susceptibility to a climatic disaster and is often concerned with the location of the system or entity. On the other hand, the vulnerability research in the broader area of economic development is concerned with vulnerability to, poverty for example, wherein the interest is to assess whether or not an economic decision making unit becomes worse off (in terms of outcomes) in the event of a climatic or non-climatic shock given its characteristics. Vulnerability is viewed both as a component of poverty as well as a determinant of poverty in the literature on poverty.

- Vulnerability is sometimes seen as a threshold value or tipping point which can be described as a degree of acceptable damage (Joakim *et al.,* 2015). The shifting of the threshold or tipping points is seen as the responses to moderate or deal with vulnerability. Though there is a vast literature on the theoretical development in the conceptualization and analysis of vulnerability, this discussion is limited to vulnerability and assessment in the context of climate change only.

## Evolution of vulnerability assessment

Vulnerability assessment is generally done in a number of different contexts and in view of different stakeholders. However, three important contexts for vulnerability assessment can be identified. These three contexts have different goals, varying information needs and thus will lead to different policy implications. These three contexts are related to fixing long term mitigation targets, identification of vulnerable regions for providing international assistance and for recommending adaptation measures for different regions or sectors. The evolution of vulnerability assessment in terms of focus, frameworks and methods broadly reflect these three decision contexts. The assessments concerned with mitigation aspects focus on biophysical impacts of climate change and are usually referred to as impact assessments. Following such impact assessments are the first and second generation vulnerability assessments that increasingly recognized the importance of non-climatic factors in determining vulnerability. These vulnerability assessments are then followed by what are referred to as adaptation policy assessments whose purpose is to identify adaptation strategies and are more policy oriented. These assessments clearly recognize the 'facilitation' and 'implementing' aspects of both mitigation and adaptation and differentiate between adaptive capacity and adaptation.

- **Approaches to vulnerability assessment:** 'Outcome vulnerability is conceptualized as 'end point' analysis where in the impact of climate change is examined on productivity or production of a particular crop or animal species either through simulation modeling or through physical experimentation. This is also referred to as biophysical impact assessment or first generation vulnerability assessment. Such assessments 'superimpose future climate scenarios on an otherwise constant world to estimate the potential impacts of anthropogenic climate change on a climate-sensitive system' (Fussel and Klein, 2006). The emphasis gradually shifted to derive policy lessons from vulnerability assessment as the purpose of such assessment was to identify strategies that reduce vulnerability of the systems or populations concerned.

The socio-economic approach to vulnerability assessment proposes that the attributes of the system or entity of interest predispose it to the adverse impacts of an external shock (climate change or variability) (Adger and Kelly, 1999) and thus it is referred to as 'starting point analysis'.

The integrated approach combines both these approaches integrating bio-physical and socio-economic dimensions of vulnerability. As the vulnerability assessments evolved, more non-climatic data became a part of such assessments.

- **The IPCC-AR4 framework of vulnerability assessment:** Though there are varying conceptualizations and definitions of vulnerability in the context of climate change, the one given by the IPCC is adopted in a large number of studies (Schneider *et al.,* 2007). IPCC in its 3rd and 4th Assessment Reports define vulnerability a "The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy *et al.,* 2001). This conceptualization views vulnerability as a residual impact of climate change: the sensitivity and exposure together determine the potential impact which will be moderated by adaptation. Adaptation is the manifestation of adaptive capacity.

Sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli". It is determined by demographic and environmental conditions of the region concerned. Exposure is defined as "the nature and degree to which a system is exposed to significant climatic variations". Thus, exposure relates to climate stress upon a particular unit of analysis. Adaptive capacity is "the ability of a system to adjust to climate change, including climate variability and extremes, to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

- **Change of vulnerability assessment framework by IPCC with AR-5:** The recent literature suggests that the risks due to climate change are also a result of complex interactions among social and ecological systems and the hazards arising out of climate change rather than being externally generated alone. Various facets of these interactions have to be carefully differentiated to understand risk to inform policy making for risk management. The AR 5 framework emphasizes these aspects as well as that the very components of vulnerability and risk will also interact with the contextual factors of development pathways and the climate systems (Oppenheimer, *et al.,* 2014).

- **Vulnerability – a component of risk assessment:** The AR5 proposes a different framework where in vulnerability is placed as one of the determinants of risk, the other two being 'exposure' and 'hazard'. The definitions given by AR 5 for risk and its components (Oppenheimer, *et al.,* 2014) are given below:

## Methods of vulnerability assessment

Considering that the definition of IPCC is the most adopted one in the context of climate change vulnerability, any assessment should ideally capture the future climate, examine its potential impact on agricultural performance (e.g. crop growth and yield) and then see how adaptation action reduces that impact. The resultant impact is considered as vulnerability. Such an operationalization of vulnerability assessment was done through crop simulation modeling (e.g. Olsen *et al.,* 2000) and econometric methods (e.g. Ajay Kumar and Pritee Sharma, 2013). Such methods are data and skill intensive and cannot easily be scaled up.

'Indicator method' is the most used method in assessing vulnerability for identifying hot spots of vulnerability to climate change (Rama Rao *et al.,* 2013). The method involves identification of indicators of different dimensions of vulnerability and risk, normalization and aggregation. The choice of such methods is dependent on the nature of data, skills available, etc.

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# 32. Construction of Vulnerability Index

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Fourth Assessment Report of IPCC defined vulnerability as a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). It implies that assessment of vulnerability of a study unit involves integration of the three components *viz.*, exposure, sensitivity and adaptive capacity. Further, each component is multi-faceted and not directly measurable. Several attributes together reflect a component. Data on an attribute has to be translated in to a meaningful indicator that enables comparison among study units. Identification of relevant indicators and choosing a few that together reflect the component is the most crucial step in construction of vulnerability index. Finally, the component is to be quantified by combining the indicators chosen. The data on different attributes may be available at varying spatial scales and temporal (year) scales. All these data are to be brought at the level of unit of analysis (study unit). This calls for development of a database to handle time-series data gathered on various spatial scales, say, grid, district, etc.

## Identification of relevant indicators

Identification of relevant indicators should be guided by the theoretical considerations and causal processes of vulnerability. As per the framework of IPCC's AR4, there are 3 sub-components of vulnerability, *viz.*, exposure, sensitivity and adaptive capacity. A set of indicators that together reflect or describe the phenomenon of a sub-component as per its definition are to be identified. It is desirable to have a comprehensive list of indicators and then screen them based on criteria such as relevance, correlation, data availability, relationship with the phenomenon, etc. for including in the analysis. Rama Rao *et al.* (2016) included indicators such as rainfall, degraded and wastelands, available water holding capacity of soil, etc. in sensitivity component. The indicators such as irrigation, nutrient use, density of livestock population, access to regulated markets, etc. were included in the component of adaptive capacity. Indicators that capture probable adversity of climate in future (projected) which has bearing on agricultural production were derived by computing change in rainfall, drought, dry-spells, temperature and extreme events such as heat wave, cold wave, frost, 99 percentile rainfall, etc. from baseline (1961-1990) to future period of 2021-2050. The details are available in Rama Rao *et al.* (2013).

## Construction of a composite index for vulnerability

Construction of vulnerability index involves certain steps *viz.*, normalization of indicators, assigning weights to different indicators, aggregation of indicators to build a composite index for a component of vulnerability, combining component indices to construct vulnerability index and grouping of study units based on composite scores or ranking based on them.

- **Normalization of indicators:** Often data of different indicators used for construction of a composite index will have different units and measurement scales. Transforming the indicators in order to bring a common scale among indicators to be used in construction of a composite index is called normalization. Min-Max is a popular normalization technique if the objective is to assess relative vulnerability of an entity. It rescales the data using range. If an individual indicator is positively associated with the component of vulnerability, the normalized value of the indicator is computed as N = (X-Min)/(Max-Min). Where X is original indicator value; Max is maximum of X values and Min is minimum of X values. It assigns zero score to lowest indicator value (min) and one to highest indicator value (max). Zero value of the normalized indicator implies that status of the component of vulnerability of the entity is the lowest among the study units with respect to the indicator. If an indicator is negatively associated with the component of vulnerability, normalized value for the indicator is computed as N = (Max-X)/(Min-Max). The unit with highest indicator value gets zero value in this case. The composite index built by aggregating the normalized values of various indicators using this method also carries similar interpretation. The indicators used for building human development index (HDI) were normalized using this kind of technique (UNDP, 2016).

- **Assigning weights to different indicators:** Different weights may be assigned to different indicators to reflect their economic significance. There exist participatory approaches which take into account the opinion or judgment of experts to determine the weights. **Budget allocation** is one such method which asks experts to distribute N (usually 100) points over the indicators finalized. The experts have to give relatively more points for indicators whose importance they deem is high. Weight for an indicator is determined by computing arithmetic mean of points given by experts to the indicator divided by N. Rama Rao *et al.* (2013, 2016) assessed vulnerability of agriculture of Indian districts to climate change using this method.

- **Method of aggregation to construct a composite index:** Method of aggregation also has a bearing on results. It is usual practice to use linear aggregation method. It proves to be a better choice if strength indicated in one attribute can compensate weakness indicated in another attribute which is known as compensability. If some degree of non-compensability is desired in the composite, multiplicative or geometric aggregation is a better choice. Geometric aggregation rewards those units with higher scores. UNDP (2016) used geometric aggregation to construct human development index (HDI), a composite of health, education and income.

- **Combining component indices to build vulnerability index:** The composite indices need to be constructed for the components of sensitivity, exposure and adaptive capacity separately by following the above steps. Though these indices help us comparing the study units with respect to the component for which an index is built, do not necessarily possess common measurement scale. This entails a need for normalization of the component indices separately before combining them to construct vulnerability index. As done with individual indicators, the relationship of a component to vulnerability has to be kept in mind while normalizing the component indices. While sensitivity and exposure are directly related to vulnerability the component of adaptive capacity has an inverse relationship to vulnerability. Further, the steps of assigning weights to the three components and deciding up on method of aggregation are necessary to construct the composite index of vulnerability. Rama Rao *et al.* (2013, 2016) used expert based weights of 0.25, 0.40 and 0.35 to exposure, sensitivity and adaptive capacity respectively. One can expect an element of compensability among the 3 components of sensitivity, adaptive capacity and exposure and linear aggregation may be adopted. Rama Rao *et al.* (2013, 2016) used linear aggregation while assessing vulnerability of agriculture to climate change in India at district level.

- Fifth Assessment Report (AR5) of IPCC adopts a different framework where in vulnerability is conceptualized as predisposition of a system to be adversely affected. This framework views vulnerability as a component of risk management in larger context where in vulnerability along with two other components, namely, hazard and exposure determine the risk of a particular system or entity to climate change (Oppenheimer, *et al.,* 2014). Exposure refers to presence of a system that could be adversely affected and hazard refers to potential occurrence of an event that may cause loss to a system. In this case composite indices are to be constructed for the three components *viz.*, vulnerability, hazard and exposure in the first phase and resulting risk in the second phase.

- **Grouping or Categorization of study units:** Planners and policy makers usually like to have the output in the form of groups of study units like poor, better, best; which indicate action. Categorization of study units into groups should be done with consideration of normalization technique used. The study units may be categorized for sensitivity, adaptive capacity, exposure and vulnerability separately. It helps us understand the components where certain study units are lagging behind and becoming highly vulnerable. This enables the policy makers to devise some interventions that help improve resilience and reduce vulnerability. If Min-Max normalization technique is used, the composite index serves as a measure of relative vulnerability. Composite score of zero implies lowest vulnerability and a score of one implies highest vulnerability among study units. In such cases, the units should be ranked based on composite score and be divided into equal groups and the number of groups may be determined from planning perspective.

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# 33. Mainstreaming Gender Differentiated Adaptation Measures, Policies and Strategies for Climate Resilient Agriculture


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Implications of impacts of climate change on agriculture sector have far reaching consequences on livelihood and food security of country. Rainfall and temperature variability affected cropping pattern, length of growing season, quality of fruits and vegetables, intensity of pest and pathogens, increase in frequency of climate events like droughts, floods, hailstorms etc., Besides, women's roles and responsibilities being affected while men migrate to far off places in search of livelihood. Women, constitute major work force in agriculture and their workload is even doubled resulting from male migration to urban areas, a common phenomenon witnessed in rural areas. The report of the subgroup on gender and agriculture, planning commission, 2007 reported women dominance in horticulture, livestock and fisheries sectors; increasing feminization of agriculture and increased number of female headed households which reveals that female work force participation in agriculture is higher than male members.

Many National action plans on climate change focused on adaptation plans to counteract impacts of climate change like droughts, floods and hailstorms. Successful adaptation plans consider both men and women's needs to secure livelihoods as men and women differ in assets, education and income levels (FAO, 2011) Studies on adaptation plans reported impacts are gendered and therefore, men and women have specific adaptation needs and measures. A thorough review of findings on climate change impacts related to gender would through light upon the need to design strategies and adaptation plans specific to men and women rather thinking one size fits all and neutral.

## Gendered responses to impacts of climate change

Responses of men and women to climate change impacts differ from individuals, groups or communities depending upon the extent of vulnerability. Vulne*rabi*lities are defined by their exposure, sensitivity of their physical environment or given livelihood and adaptive capacity of the individual. For, example, considering agriculture as livelihood occupation men and women has differential socio economic characteristics, education and knowledge levels and access to assets, knowledge and information, extension and training, and markets and institutions etc., which primarily bring significant differences to extent of vulnerability and adaptation status. Goh. 2012, reported visible gender differences, affected by climate change impacts, in areas of food security, crop production, health, natural disasters and water and energy resources management.

The differentiated impacts of climate change on crop production have negative impacts on men and women who directly depend on agriculture as their occupation. As agriculture occupation is land based, husbands, owners of land in most countries like Bangladesh, India, etc suffer climate shocks more when compared to wives possessing landless assets (Quisumbing *et al,* 2011) Likewise, women control income earned from selling fruits and vegetable when affected with droughts and loss of water resources suffer from risk more than men in terms loss of income. These are some instances where men and women exposed to drought show varied responses to climate shocks depending on kind of assets and role and responsibilities allocation.

## Need for gender differentiated Adaptation measures for climate resilient agriculture

Women in agriculture have more knowledge in agricultural operations ranging from production to processing to storage of produce. Women's experiences and knowledge possessed useful to counteract climate change impacts and need to be factored into adaptation action plans (Kapoor, 2011). Vulne*rabi*lities to climate change are significantly felt by women more than men, considering the nature and participation in agricultural activities and are more responsive than men farmers and achieve greater success. Women farmers are not only recipients of knowledge, skills and training but also decision- makers and risk takers and henceforth gender needs for adaptation considered in policies and strategies of climate action plans. Kapoor, 2011 mentioned 4 C's while designing action plans for adaptation plans.

- **Counting Women**: Count women needs in planning, designing, implementing, resourcing and evaluating stages of all programs and schemes.
- **Converging** : Converge with programmes and schemes involving multi sectoral and multi ministerial bodies at planning and designing stage. At implementation stage involve district rual development agencies and panchayat raj institutions.
- **Capacity development** and empowerment of women and men at all levels: panchatraj (PRI), line departments and NGO's to build institutions' that contribute to adaptation plans and responses.
- **Collaborating** with all key stakeholders – scientists, NGOs, PRI, line departments, user groups for building knowledge and skills for climate resilience among men and women through innovations, local knowledge, and integration of technological interventions and convergence of resources.

## Gender Inclusive Adaptations for Climate resilient agriculture as delineated by different stakeholders

Bridging gender gap in climate policies and programmes are very important to bring gender equality and sustainable climate resilience in agriculture. The proposed strategies and polices by different stakeholders may be taken into consideration while planning adaptation strategies and plans (Kapoor, 2011).

| | |
|---|---|
| Ministry of Agriculture, ministry if Environment and forests, Ministry of Water resources | - Set gender specific objectives and indicators for meeting the identified needs bot practical and strategic needs.<br>- Incorporate gender- responsive language to promote gender equality.<br>- Set additional financial resources to meet strategic needs<br>- Build capacity development programs for women on climate change adaptation |
| Department of Science and Technology | Involve women and women scientists to document women's climate related data locally<br>Scientifically validate indigenous knowledge and then build on it. |
| Indian council of Agricultural research | Involve women stakeholders in capacity building programmes in all components- NRM, Crops and cropping systems, Livestock management, fisheries and institiuon building etc., |
| District Rural Development Agency (DRDA) | - Strengthen Women Cells by strengthening capacities of staff to meet adaptation goals.<br>- Facilitate gender-responsive, participatory assessments, monitoring and evaluation of adaptation programs and schemes. |
| Elected legislators- State and Central | - Ensure availability of gender- disaggregated data, including on all natural resources dependent livelihoods<br>- Promote equal representation of women at all decision making platforms |
| All NGO and civil society organisation | - Mobilise all women and men and build their awareness for collective action towards adaptation<br>- Promote women as drivers of change<br>- Network across stakeholders to communicate success stories to most vulnerable women<br>- Mandate a strong internal gender policy for the organization, addressing practical and strategic needs of women. |

## Conclusions

Climate change impacts are gendered. Bridging gender gap in adaptation plans with appropriate polices, strategies and programs promote gender equality in addressing practical and strategic needs of men and women equally. Creation of a gender sensitive adaptation environment will only ensure climate resilience agriculture as men and women practical and strategic needs achieved.

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# 34. Building Climate Resilience through Effective Farmers' Adaptation


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Farmers' perceptions are the most important predictor of adaptive action. It is essential to know how perceptions and actions influence one another, to understand what physical changes in climate may prompt a change in farmers' opinion, and by extension, a change in action. Beyond understanding opinions regarding the concept of climate change, understanding perceptions of climate change is of particular importance because it will influence the adaptive behavior that individuals are likely to take.

A study was conducted by Central Research Institute for Dryland Agriculture (CRIDA) in three different states of India *viz*., Andhra Pradesh, Karnataka and Maharashtra where All India Coordinated Research Project for Dryland Agriculture (AICRPDA) centers are located *viz*., Anantapur in Andhra Pradesh, Bijapur in Karnataka, Akola and Solapur in Maharashtra. A sample of 240 households @60 from each center was selected randomly for data collection representing a minimum of 20% of the population of selected area. Data was collected using a structured and pre-tested interview schedule from the farmers. Focus group discussion and interviews were conducted to elicit data from farmers.

Prolonged dry spells, rise in temperatures and rainfall outside rainy season were the major farmers' perceptions towards climate change in all the selected locations of study. Similar studies in Ethiopia and South Africa revealed that farmers experienced increased temperature and decreased rainfall (Bryan *et al.,* 2009). Results of a study conducted in Bundi district of Rajasthan, India revealed farmers' perceptions to climate change as increase in temperatures, decreased rainfall and long dry spells. Studies in several other developing countries indicate that most farmers perceive temperatures to have become warmer and rainfall reduced over the past decade or two (Gbetibouo 2008; Dinar *et al.,* 2008; Mubaya *et al.,* 2010; Deressa *et al.,* 2011).

Buying insurance, changing planting dates and cropping pattern, were the major adaptation measures practiced by farmers' towards climate change in the selected four study locations. This finding is consistent with similar study by Swanson *et al.* (2008) which reported that crop insurance was widely used by farmers in foremost region of Canada (which is under similar agro-ecological conditions) and the common feeling was that even though it might not provide sufficient returns for losses incurred it does offer some protection. It has allowed them to continue farming. Agricultural insurance can help people to cope with the financial losses incurred as a result of weather extremes. Insurance supports farmers as one of the adaptations processes and prevents them from falling into absolute poverty. Apart from stabilizing household incomes by reducing the economic risk, insurance can also enhance farmers' willingness to adapt, to make use of innovations and invest in new technologies (Anna *et al.* 2011). Usually, farmers in Anantapur sow groundnut during July last week every year. But recent trend shows that if one rain occurs during summer month of May or early June, some of the farmer's are going for sowing to reap some benefit thinking the worst case scenario may occur during that year i.e., drought. These identified adaptation strategies should be promoted and supported by governmental and non-governmental agencies if, farming situations in India has to be made resilient to climate change impacts.

Small farmers usually migrate during the event of failure of monsoon to work as contract labour which also serves as one of the adaptation practices in rainfed areas (Ravi Shankar *et al.,* 2013). Water harvesting is one particular practice that has proved to be climate resilient among farmers and reaped rich dividends to them. Water harvesting along with the use of modern micro-irrigation practices such as sprinkler and drip irrigation as an adaptation strategy is well established and should be promoted aggressively in similar dry regions of the world.

Attitudes of farmers' towards climate change provide feedback to the research for developing tools for the decision support systems. Farmers' attitudes towards climate change are likely to be affected by their opinion about acceptable adaptation strategies. A majority of the farmers (more than half of the sample population) agreed with all the attitude statements in the four study locations. Of particular interest is the way with which farmers' echoed similar response about the rise in temperatures, decrease in total amount of rain, incidence of pests and diseases and that human activity is responsible for climate change. It is known that some people strongly believe that climate change is occurring and attribute it to human activity, others do not believe that it is happening, and still others are uncertain (Maibach *et al.,* 2009). While majority of farmers' believe that local or traditional knowledge systems can offer solutions to climate change, they, also acknowledge to the fact that of late traditional knowledge/indicators for rain prediction are failing. Farmers' from three out of four study locations in disagreed to the fact that they do not take climate change into account while thinking about their future. Farmers' were eager to have more information on options or choices to respond to climate change. Simultaneously, adaptation to other problems is more important than adaptation to climate change for farmers. This suggests that climate change is one of the many problems (not the foremost) that farmers' are facing in their daily decision matrix like availability of inputs, credit, government support mechanisms and markets etc. Farmers' felt that government support to adapt to climate change is inadequate and needs to be further accelerated like by conducting awareness campaigns, trainings and education etc. Farmers' have put tremendous responsibility upon scientists to solve the climate change threat and scientists should live up to the responsibility in providing good crop varieties that should possess drought tolerant and flood resistant characteristics. In this analysis, it was found that majority of farmers positively agree with attitude towards climate change statements which augurs well for current and future adaptation actions.

## Barriers to climate change adaptation

The major barriers to climate change adaptation identified from the study locations were lack of access to credit, labour and access to water. From farmers' point of view, awareness about adaptation practices is by itself not sufficient, but has to be supported with capital and labour for successful adaptation. Measures which need attention by policy makers regarding climate change adaptation that were expressed by farmers were pollution control, afforestation and development of irrigation projects.

## Conclusion

A better comprehension of farmers' perceptions towards climate change, current adaptation decisions, is needed to promote effective futuristic agricultural adaptation policies. Since attitudes precede actions, it can be safely assumed that the attitudes of farmers (here found positive) towards climate change precede their future positive adaptation actions. Agricultural extension and education are crucial to farmers in providing climate resilient knowledge and practices for successful adaptation. Adaptation through transformation has the potential to become an inclusive, engaging and empowering process that contributes to alternative and sustainable development pathways.

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# 35. Facilitating Rural Stakeholders to Practice Climate Smart Agriculture-Experiences from NICRA

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Climate change is now very much with us, and the implications are daunting particularly the rural stakeholders with minimum structural support and facilities. These marginalized communities are not equipped with needed capacities to tackle the climate based challenges. Efforts to reduce food insecurity must include building the resilience of rural communities to shocks and strengthening their adaptive capacity to cope with increased variability and slow onset changes.

In the light of aforesaid facts, the Indian Council of Agricultural Research (ICAR) launched a flagship initiative '*National Initiative on Climate Resilient Agriculture*' (NICRA) during XI Plan in February 2011, and during XII Plan it is referred as '*National Innovations in Climate Resilient Agriculture*' (NICRA) to meet the challenges of sustaining food production in the context of climate variability. The present note describes how various strategies like demonstration of site specific technology packages on farmers' fields for adapting to current climate risks were implemented at grassroots level to impart capacities for various stakeholders on climate resilience.

## Experiences of NICRA

Enhancing the resilience of Indian agriculture to cope with climate variability and climate change is vital to the livelihood security at household and village level, and to meet the food requirements of the country. It is in this context, the crucial component of NICRA, technology demonstration which deals with the deployment of suitable extension methodologies and strategies for adaptation and resilience to Climate Change at grass root level for enhancing climate resilience at village level.

## Stakeholder and Community Partnerships

Technology demonstration component of NICRA was implemented in a cluster of villages from each of selected 153 districts which are vulnerable to climate change impacts of extreme events like droughts, floods, cyclones, heat wave, cold wave, frost and salinity. The program was piloted by the KVK or Farm Science Centre, under the technical guidance of Agricultural Technology Application and Research Institutes (ATARI). Indian Council of Agricultural Research (ICAR) Institutes and State agricultural university (SAU) systems located near to selected vulnerable district. At the district level, the project is being implemented by selected

KVK/ICAR institute/SAU and at the village level by institutions established in the villages such as Village Climate Risk Management committees (VCRMCs) for ensuring effective participation by farming community.

## Community Institutions facilitated and strengthened under ICAR-NICRA

The focus of the programme is not only to demonstrate the climate resilient agriculture technologies but also to institutionalize mechanisms at the village level for continued adoption of climate smart practice in sustainable manner. This also results in strengthening the existing institutional mechanisms at the field level for successful technology adoption and up scaling. It is important to have appropriate institutional mechanism in place for successful implementation and sustainability of any agricultural development programme. Hence *institutional interventions like community seed bank, fodder bank, farm machinery custom hiring center etc. are being implemented under NICRA through active involvement of farmers /stake holders across the districts.* The activities of these institutions are given below.

## Village Climate Risk Management Committee (VCRMC)

A VCRMC representing all the categories of farmers in the village is formed with the approval of gram sabha in all NICRA villages. This committee is fully involved in the NICRA programme and implementation of technological interventions VCRMC participates in all village level discussions including planning, finalizing interventions, selection of target farmers and area, and liaison with gram panchyat and local elected representatives. VCRMC maintains joint bank account which is used for all financial transactions under NICRA including maintaining farmer's contributions for different activities, handling of payments recovered from custom hiring centres.

## Custom Hiring Center

Timely access to farm machinery for sowing, harvesting etc. is an important component of adaptation strategy to deal with climatic variability. Therefore an innovative institutional arrangement in the form of a farm machinery custom hiring center has been created in each of the 100 selected villages. The rates for hiring the machines/ implements are decided by the VCRMC. The revenue generated would be used for repair of farm implements and maintenance of custom hiring centre.

## Seed Bank as contingency measure

Provision timely seed for farmers (non hybrids but stress tolerant improved varieties) is one of the most relevant institutional interventions relevant to meet the goal of NICRA. In this process, a group of 20-25 farmers has been selected for seed production of relevant varieties for 2-4 major crops of the village in all the 100 districts. The farmers group is trained and given seed and money to organize the activity.

## Fodder Bank for improving livestock productivity

Livestock is one of the most important components of dryland farming systems, which plays a stabilizing role during climatic shocks. Sharp reduction in fodder production from private as well as common lands due to either drought or flash floods is the key impact of climatic variability on livestock production. Hence, Fodder Bank is a very important institutional arrangement for enhancing climate resilience of livestock production systems in dry land/ rainfed regions. Enhancing production, conservation and storage of fodder by involving SHG's / User groups is the objective.

## Capacity building for climate resilience

Adaptation to climate change and mitigation efforts in agriculture, together with keeping up with production challenges, will require more skilful farmers, herders and fisher folk. Formal and informal training resources should be made accessible to them. Capacity development should include strategic thinking for identifying and managing risk and climate variability impacts, technical knowledge for climate-smart agricultural practices, ecosystem management and monitoring, business management decisions, all with a "problem solving" focus. Training programmes should also aim to attract younger generations to agriculture.

## Conclusion

The agricultural and allied sectors (crops, livestock, forestry, fisheries etc.) must therefore transform with collective action of various stakeholders to face challenges of climate variability in order to have food security. It should pave the path for economic growth and poverty reduction with channelized efforts of institutions developing human and social capital which can tackle the effects of climate change impacts.

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# 36. Web based Interactive Thematic MapGen Tool


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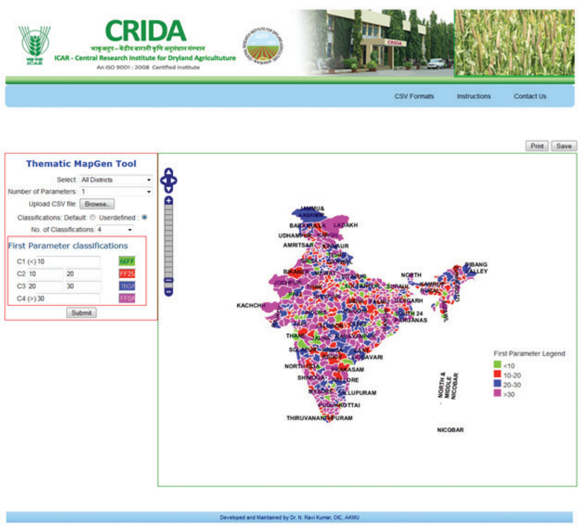
A thematic map is a type of map, which depicts a particular theme connected with a specific geographic area. These maps can be used to describe agricultural, weather, sociological, economic, social, cultural, or any other aspects of a city, state, region, nation, or continent. The great advantages of thematic maps in the information transmission, storage, conversion and display have become essential tools and means in investigations and studies, analysis and evaluation, forecasting, planning and design, command and management. And thematic map symbol is the most basic and important component of the thematic language and plays an important role in the expression of the thematic content. Varied users leads to diversity and complexity of the thematic symbols and expression methods and most of the thematic maps do not have a fixed format and norm as topographic map. At the same time, users are not very familiar with use ofgeographic information system (GIS). Many GIS software are commercial in nature. User needsto have minimum knowledge on GIS software for creating of any kind of map. This "Web based Interactive Thematic MapGen Tool" was developed to make India thematic maps free of cost and user no prerequisite knowledge required. User-friendly interactive frontend was developed to create State wise India, District wise India and District wise State thematic maps based on their objectives.This Tool is an enterprise mapping service that allows you to easily createand save interactive maps. This application does not store user data. Uploaded date will be deleted from the application as soon as application session/page is closed.

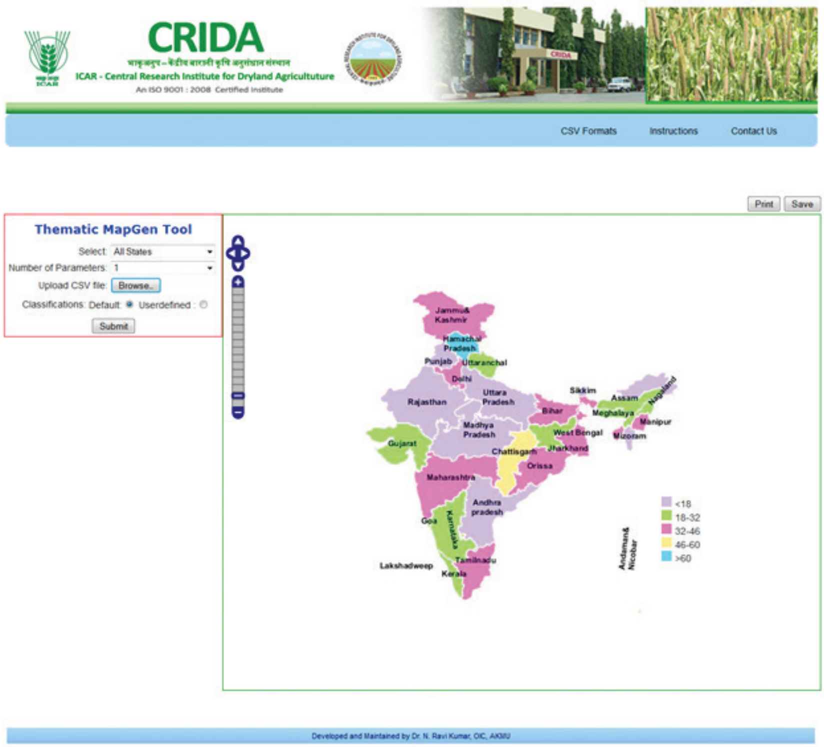
## How does it work?

It works on open-source Geoserver. It allows users to share process and edit geospatial data, used for Publishing Web based Maps. GeoServer provides support for a broad selection of simple feature data stores, including property files and shape files. Users are able to generate single and multi layer web based maps. The map is dynamically displayed on the web page with the help of OpenLayers. It is an open source JavaScript library.



## How to Generate Map

It is an interactive tool which receives user input parameters namelyType of map, number of Parameters projected on the map,Data file in the CSV format and number of data Classifications. Firstthree inputs are mandatory;map cannot be generatedwithout first three inputs parameters. By default application takes 5 data classifications if user is not defined. The CSV file structure is first column represents id of the administrative boundary shape file, second column represents name of the administrative and the third column onwards, each column represents a parameter of the user data of selected administrative boundaries. After uploading the data file in .csv format, the data has to be classified by the useras per requirement and give rang of values along with colour per each class. The same classification process applied for rest of the parameters. Colour can be changed by clicking on the colour. On submissionthe generated thematic map displays on the screen.




Bamboo plantation as live check dams in degraded Mahi Ravines of Gujarat

# 37. Water Harvesting Check dams for Climate Resilient Agriculture in Rainfed Regions

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The rainfed regions of India are characterized by aberrant behaviour of monsoon rainfall, eroded and degraded soils with water and nutrient deficiencies, declining ground water table and poor resource base of the farmers. The major constraint is low and unstable yields in rainfed areas with large yield gap. In addition to these, climate variability including extreme weather events resulting from global climate change poses serious threat to rainfed agriculture. In rainfed regions, rainwater is the main source of water for agriculture but its use efficiency for crop production is low and varies from 30-45%. In monsoon dependent country like India, the rainfall is received in 100 days in 100 hours; therefore, there is a great need of storage of surplus runoff. The farm pond technology is one of the best technologies for climate resilient agriculture and is gaining of popularity, however, it is not feasible for marginal farmers due to area lost for cultivation and cost/unit of water harvested. In locations, where natural streams are available, the check dams can be an alternative for runoff harvesting and recycling to cope with climatic aberrations such as mid seasonal and terminal droughts and floods.

Check dams are constructed to store rain water and silt on the upstream side. Depending upon size of nala, its slope, watershed area and severity of the problem, suitable type of check dam can be selected. Temporary check dams made of locally available material like brushwood, log wood and planks are used in small gullies, mostly in the upper reaches where runoff is less. Semi permanent check dams made of loose boulder, and/or dry stone packing are recommended in small to medium gullies. Gabion check dams are preferred in medium gullies in the middle reaches. Permanent gully control structures/water harvesting structures are used in medium to large gullies carrying more runoff especially in lower reaches. The effect of check dams on groundwater recharge, water availability, production, productivity, livelihood improvement were reported by several scholars (Wani *et.al., 2007*, Sharda *et al*.,2005 , Joshi *et. al*., 2005, Kumar *et. al.,* 2004; Dhyani *et. al*., 2016).

**Temporary check dams**

For stabilization of gullies through vegetation is a difficult task. Temporary mechanical measures are adopted to prevent washing away of the plantation by large volume of run-off that provides to establish the vegetation. Vegetations once established will be able to take care of the gully. Followings are some such mechanical measures / structures; a) Check Dams; - (i) Temporary check dams, (ii) Brush dam, (iii) Semi permanent check dams. b)

Loose Rock Dam c) Log Wood Dam. Vegetative live check dams are constructed in upper reaches of the catchments or watershed. The grasses or baboo type of species can be used as live or vegetative check


**Earthen check dams:** Earthen check dams can be defined as small earthen embankments across gullies or streams to reduce the runoff velocity, stabilization of gullies and store the runoff water. The size of the gully plug/checkdam depends on width length and bed slope of the gully, anticipated runoff and proposed plantations in the gully. The height of the gully plug/earthen checkdam usually kept as 0.9 to 1.5 m, top width 1 m for small gullies and 2 m for medium gullies, side slopes 1:1, and length of the gully plug will be kept as equal to the channel width. The spacing depends upon the gradient of the channel bed. Usually for 3% slope every 30 m distance gully plug can be constructed. These can be constructed at upper reaches of the catchment or watershed. The benefits of these check dams will be stabilization of gully beds and banks, deposition of sediments and nutrients, water storage thereby enhancing soil moisture and better plant growth. Reduced the runoff and soil loss by 80%.

**Bori bund checkdam:** Bori bunds is a type of embankment constructed across the gullies using polythene bags (empty cement or fertilizer bags) filled with the locally available sand or soil for blocking active and erosion-prone first-order streams. It is an effective method to slow down the speed of flowing water of the stream in any area. Usually where earthen gully plugs is not able to control the runoff flow these structures can be constructed. The size of the bori bund depends on width, length and bed slope of the gully, anticipated runoff and proposed plantations in the gully. The height of the bori bund usually kept as 0.9 to 1.5 m, top width 0.6 m, side slopes 1:1, and length of the gully plug will be kept as equal to the channel width. The spacing depends upon the gradient of the channel bed. Usually for 3% slope every 30 m distance one bori bund can be constructed. For uniform distribution of soil moisture to the plantations, minimum spacing and minimum height can be maintained. Medium Gullies and deep gullies with complete sandy soils. The locations, where earthen gully plugs is not able to control the runoff flow (Rao *et al.,* 2012). The benefits will be stabilization of gully beds and banks, deposition of sediments and nutrients, water storage thereby enhancing soil moisture and better plant growth. Reduced the runoff and soil loss by 80%.


Earthen and bori bunds/sand bag checkdams

## Permanent gully control/water harvesting structures

Permanent Gully Control Structures are necessary where vegetative or temporary structures are not adequate. Permanent Structures such as masonry check dams, flumes or earth dams supplemented by vegetations are provided to convey the run-off over critical portion of the gully. Principal types of permanent structures are drop spillways, drop inlet spillways and chute spillways.

**Drop spillway:** The drop spill way is a weir structure. Flow passes through the weir opening, drops to an approximately level apron or stilling basin and the passes to the downstream channel Drop spillway may be constructed of reinforced concrete, plain concrete, rock masonry and concrete blocks with or without reinforcing or gabions. The spillway is an efficient structure for controlling relatively low heads, normally up to 3.0 meters.

**Drop inlet spillways:** A drop inlet spillway is a closed conduit that carries water under pressure from above an embankment to a lower elevation. The usual function of a drop inlet spillway is to convey a portion of the runoff through or under an embankment without erosion. It is a very efficient structure for controlling relatively high gully heads usually above 3.0m.

**Chute spillways:** A chute spillway is an open channel with a steep slope, in which flow is carried at a supercritical velocity. It consists of an inlet, vertical curve section, steep sloped channel and a out let. Reinforced concrete is widely used to construct chute spillways and adopted particularly to high overfall gullies, detention dams to reduce the required capacity.

## Brick/stone masonry check dams

In locations, where natural streams are available in lower reaches of the watershed, the brick/ stone masonry check dams can be an alternative for runoff harvesting and recycling to cope with climatic aberrations such as mid seasonal and terminal droughts and floods. The construction of brick stone masonry structures involves high cost without any scheme/ programme the adoptability by these structures is low. The rubber and plastic check dams are the cost effective and easy for construction. These will reduce the construction difficulties. These are easily adopted by watershed management schemes for rainwater harvesting and water management practices for a long period without incurring any substantial maintenance cost.

Brick, Stone masonry checkdams

Water harvesting checkdam

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# 38. Watershed Treatment Technologies for Sustainable Production

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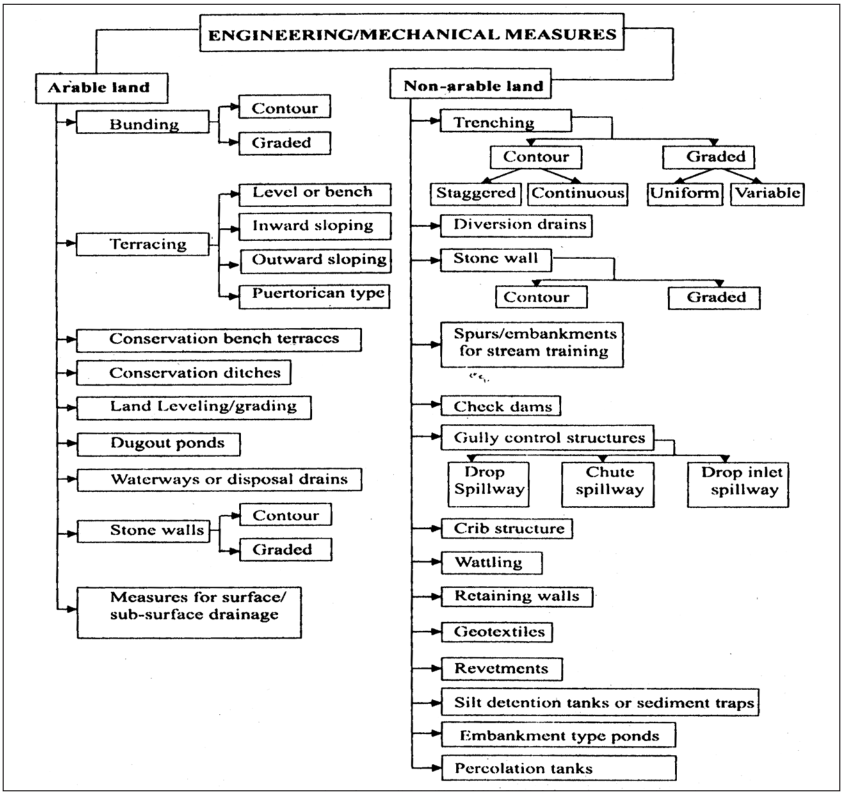
The suitability of a given type of conservation measure in an area depends upon slope, rainfall (amount and distribution), soil type and depth, water holding capacity, location of impervious layer, agricultural practices, power/equipments used and economics. Lands having less than 2% slopes do not require any of the structural measures in general. Lands up to 10% slope may require narrow or broad based terraces. The broad based terraces are useful when land holdings are large and machinery is used for farming operations. It is doubtful if narrow based terracing i.e. blinding be of any practical use in lands having slopes more than 6%. In high rainfall areas, such land slopes will require uneconomically closer spacings resulting in more loss of area. It is difficult to achieve uniformity in blinding practice on lands steeper than 4% and in any case steeper than 6%. For lands with slopes above 10% and up to 33%, bench terracing is an effective measure as it breaks the length and also reduces the degree of slope. It, however, restricts farming operations, is expensive and significant area is lost out of cultivation.



From the point of view of efficient water management, graded terraces are to be adopted in areas where rainfall is more or for areas where inspite of moderate rainfall, runoff disposal is a problem. Level terraces are for drier tracts with scanty or erratic rainfall where moisture conservation is of prime importance. Area lost out of cultivation is highest in bench terracing while under blinding, 5-10% area is lost which can be put to alternate land uses.

**Importance of conservation structures**

- Increasing the time of concentration and thereby allowing more runoff water to be absorbed and stored in the soil profile due to enhance infiltration opportunity time.
- Intercepting a long slope into several short ones, so as to maintain less than the critical velocity for the runoff water.
- Protection against damage owing to excessive runoff.
- Reducing the steepness (degree) of slope.
- Terracing/bunding is the most effective and widely used practice for controlling or preventing erosion on agricultural lands in different agro-ecological regions

## Area treatment measures for arable lands

### Bunding

- Contour blinds are constructed along approximate contours (with permissible deviations) for moisture conservation.
- Side bunds are constructed at extreme ends of the contour bunds running along the slope.
- Lateral bunds are constructed along the slope in between two side bunds in order to prevent concentration of water along one side and to break the length of contour bund into convenient bits.
- Supplemental bunds are constructed between two contour bunds so as to limit a horizontal spacing to the maximum required.
- Marginal bunds are constructed along boundaries of the micro-watersheds, road margins, river or stream margins, gully margins etc.
- Graded bunds are constructed along a predetermined grade (uniform/variable) for safe disposal of excess runoff.
- Broad based bunds are adopted for soil and moisture conservation in large land holdings where farming is done by machines.

Shoulder bunds are constructed on the outer end of bench terraces to contain runoff and soil loss usually in outwardly slopping terraces.

**Contour bunding:** For slopes ranging between 2-6% with scanty or erratic rainfall (less than 800 mm annually),contour bunding is practiced to intercept the runoff flowing down the slope by an embankment with either open or closed ends to conserve moisture as well as reduce erosion.Contour bunds can be adapted on most types of relatively permeable soils that are alluvilial, red, laterite, brown, shallow, medium black except the clayey deep black soils.

**Graded bunding:** The function of graded bunds consist of constructing wide and relatively shallow channels across the slope, very near the contour ridges are and at suitable vertical intervals. These terraces act primarily at drainage channel for inducing and regulating the excess runoff water and draining it with a mild and non-erosive velocity. These bunds are adopted in areas receiving rainfall exceeding 750mm particularly in soils having infiltration rate less than 8mm per hour.

**Peripheral bunds:** The bund which is constructed at periphery of the field, where the chances of formation of the gully, elongation of gully head, rills and ravines are known as Peripheral bund. This prevents erosion, further elongation of gully head etc.

**Field bunds:** These bunds are constructed between field across the slope to prevent soil erosion and formation of rills. This bund prevents soil and nutrient losses.

**Bench terraces:** are flat beds constructed across the hill slopes along the contours with half cutting and half filling. They serve as barriers to break the slope length and also reduce the degree of slope thereby eliminating the all erosion hazards. Experiences show that, construction of dry bench terraces even up to 40 to 50% slope in NE region are feasible (Prasad, *et al* 1987 & Satapathy, 2000). The vertical interval of such terraces should not be more than 1.0 m. Such measures can be adopted where soil depth is more than 1 m. Bench terraces can also be developed with vertical stone walling and are in use by the farmers of the region. Side bunds on the outer edge of the terrace should be provided to prevent slipping down of soil and overtopping of excess runoff from the terraces. To maintain top soils in terraces, the construction should start from the foot hills. There are three types of terraces mostly using. These are

**Level bench terraces:** Benches are almost leveled to ensure uniform depth of impounding water. This type of bench terrace is used for paddy cultivation.

**Inwardly slopping bench terraces:** Benches are made inward slopping to drain runoff as quickly as possible. These types of bench terraces are preferred for cultivation of tuber crops such as potato, ginger, turmeric, and sweet potato which are susceptible to water logging.

**Outwardly slopping bench terraces:** Benches are made outward slopping and these are used in low rainfall areas.

**Puertorican or California type of terraces:** These terraces are formed by gradual conversion of land between two barriers into terrace by natural leveling process. Mechanical barriers (bunds) or vegetative barriers (grasses or shrubs) or combination of both, are laid along the contours. Due to ploughing and interculture operations soil is eroded and gets deposited at the barriers. Thus, in due course terraces are formed.

**Half-moon terraces:** The half-moon terraces are constructed for planting and maintaining saplings of fruit and fodder trees in horticulture and agro-forestry land use system. The construction of this type of terrace is made by earth cutting in half-moon shape to create circular level bed having 1 to 1.5 m diameter.

## Area treatment techniques for Non Arable Lands

Four land capability classes *viz.* V, VI, VII, VIII have one or more limitations of the slope, erosion, stoniness, rockiness, shallow soils, wetness, flooding etc. which make them usually unsuited for crop production. There use is mainly limited to pasture, forest, wild life & recreation. These lands are generally confined to upper reaches of watershed and have an undulating topography and are foci for the soil erosion. In lands with steep slopes and subjected to the soil erosion, vegetative cover do not established. Due to lack of vegetative cover soil erosion is accelerated transporting large amount of sediment in to streams below. Uncontrolled runoff from the sloping lands also causes extensive damage in lower reaches of the watersheds.

In order to prevent the degradation of these lands, vegetative and mechanical measures are employed together and are complimentary to each other. Mechanical measures act like the foundation of building whereas the vegetative measures act like super structure which helps in improving the productivity of non arable lands. These lands have a great potential for producing fodder, fuel, minor forest produce, fruits and low quality timber. These lands having some water conservation measures.

The practices such as contour trenching, gradonies, installation of temporary and permanent gully control structure, construction of sediment retention structures and retaining walls, reclamation of ravine lands, improvement and management of grass lands and rehabilitation of mined lands can be adopted for soil and water conservation measure in non arable areas of watershed.

**Contour trenches** are any form of depression or micro pit or trench constructed over the land surface. In order to prevent soil erosion and to absorb rainwater in non arable lands, trenches constructed along the contours (called contour trenches) on hill slopes above 15% with vegetative supports for forestry and horticulture land uses. Generally trenches may be dug with a cross section of 0.30 m x 0.30 m at 1 to 2 m vertical interval (Thansanga, 1997). For proper drainage of excessive runoff, they may be connected with longitudinal drains and drop pits. They are called continuous when there is no break in length and maximum length can be 100 to 200 m long across the slope depending on the width of the field. However, when these are laid scattered with maximum length of 2 to 4 m, they are called staggered contour trench. The trenches may be trapezoidal or rectangular in cross section but flatter upstream side slopes are preferred in order to minimize the risk of scouring by incoming runoff.

# 39. Climate Smart Soil and Water Management Techniques in Paddy

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Alternatives to continuous flooding of rice have been the research focus over the past few years because of climate change. Flooded rice fields emit methane and are important contributors to the increasing atmospheric methane concentration. Anaerobic decomposition of organic material in flooded rice fields produces methane (CH4), which escapes to the atmosphere primarily by diffusive transport through the rice plants during the growing season. Upland rice fields, which are not flooded, do not produce significant quantities of CH4, account for approximately 10 per cent of the global rice production and about 15 per cent of the global rice area under cultivation.

Modified crop establishment practices like System of Rice Intensifications (SRI), direct seeding in puddled and unpuddled soil (aerobic rice), minimum/zero tillage conservation agriculture have been looked as possible alternatives to discount enormously on water input in rice cultivation.

## Direct Seeded Rice

Direct seeding of rice (DSR) is considered as one of the potential alternatives to transplanted rice. It may solve the problem of emerging shortages and high costs of water and labour. There is potential of 20-30% saving of irrigation water with direct seeding compared to transplanted rice.

## Agronomic practices:

A seed rate of 20-30 kg/ha is found to be optimum for DSR. Sowing of direct seeded rice should be completed in first fortnight of June. A row spacing of 20 cm and seeding depth of 2-3 cm should be maintained for proper germination and better crop establishment. Placement of seeds below 3 cm adversely affects the dynamics of seed emergence due to rapid drying of the soil surface in hot summers.

**Irrigation management:** There is a considerable difference in soil physical, chemical and biological properties between direct seeded and puddled rice. A heavy pre-sowing irrigation 2-3 days before is advisable. Due to high temperature in the month of June, there is rapid loss of moisture from the surface soil, therefore, immediate light irrigation (30 mm) after seeding is necessary to facilitate germination. Subsequent irrigation depends on the soil moisture status and the amount of each irrigation should be adequate enough to bring the upper 20 cm soil layer to field capacity. Field should be kept moistened (not flooded) throughout the season to avoid moisture stress.

Direct seeding under drip

**Iron deficiency:** Micronutrient deficiency is commonly seen in DSR due to absence of reduced conditions in the soil. Symptoms of Fe deficiency include intervenal chlorasis of new leaves, decreased dry matter production; entire plant becomes chlorotic and dies if deficiency is severe. To overcome this, Fe-efficient varieties should be grown. Addition of organic matter (crop residues, FYM etc) and a foliar spray of 1% solution of ferrous sulphate in water or ferrous ammonium sulphate are recommended for the management of iron deficiency. Water should be kept standing in the field if acute deficiency persists.

**Zinc deficiency:** Zn deficiencies appear 4-6 weeks after sowing. Zn deficiency can be efficiently corrected by soil application of $ZnSO_4$ (Zinc sulphate). $ZnSO_4$ being highly water soluble is preferred over ZnO. In case, deficiency symptoms appear in the field, a dose of 10-25 kg/ha of $ZnSO_4$, $7H_2O$, $7H_2O$ mixed with sand (1:3) should be applied over the soil surface.

Iron deficiency in direct seeded rice

## Direct wet seeded rice under puddle condition (Wet seeded rice)

Direct seeding under puddle in rice is becoming a popular alternative to transplanting system as it reduces the labour and the cost of labour and the grain yield is often higher than transplanted rice under irrigated condition.

 

Sowing with Drum seeder Field after drum seeding

Direct sowing pre-germinated seeds in puddled soils in the irrigated and rainfed lowland ecosystems can easily avoid raising nurseries and transplanting operations. The direct sown crop also matures earlier than the transplanted crop by 8-10 days. The main problem in direct sown crop by broadcast seeding pre-germinated seeds is the unevenness in the plant stand and population density. These problems can be overcome by paddy drum seeder.

## Benefits of the direct drum seeded rice are as follows:

Water saving is possible to certain extent because it is not needed to nursery, prepare and puddle the main field early.

- Crop duration is reduced by 7-12 days making it possible to have short duration pulse crop after two direct sown rice crops.
- Low investment and less labour requirements.
- Eight row drum seeder can be used as substitute for transplanting when droughts/floods occur where raising nursery is not possible.

## Aerobic Rice-A Potential Water Saving Technology

Aerobic Rice is a new development in water saving technologies. Well ploughed, and no or very little clods/clumps in field is required like any dry land crops. **Seed rate:** 25-30 kg/ha(varies for Hybrids and High Yielding Varieties). Seeding can be done manually or by seed drill in shallow furrows of 2-3 cm depth, at a spacing of 20X10 cm for HYVs and 20X15 cm for Hybrids. Soil must to be kept aerated to get the advantage of aerobic cultivation. Need based irrigation (5-7 days interval) is needed to maintain moist situation upon noticing visible symptoms of hairline cracks on soil surface. Maintenance of saturated condition at critical stags of active tillering, panicle initiation, flowering to grain filling stage is essential. (Fig.).

**Weed Management:** Weeds are one of the major constrains to aerobic rice production system, as dry-tillage, alternate wetting & drying conditions are conducive to germination, growth of weeds causing grain yield losses of 50-91%. Sequential application of Pendimethalin 30 EC @ 1.5 kg a.i./ha. application as pre-emergence 1-2 days after sowing, followed by Bispyribacsodium 10% SC @ 20 g a.i/ha at 3-4 leaf stage of weeds is recommended.

## Alternate Wetting & Drying (AWD)

Alternate wetting and drying (AWD) is a rice management practice that reduces water use by up to 30% and can save farmers money on irrigation and pumping costs.

AWD like practices have continued to spread. A large potential exists for GHG reductions from rice paddies through the use stematically introduced AWD optimized for GHG mitigation. At present, AWD is widely accepted as the most promising practice for reducing GHG emissions from irrigated rice for its large methane reductions and multiple benefits.

## Benefits of AWD

### 1. Reduced water use.

By reducing the number of irrigation events required, AWD can reduce water use by up to 30%.

It can help farmers cope with water scarcity and increase reliability of downstream irrigation water supply.

**Greenhouse gas mitigation potential:** In the 2006 IPCC methodology, AWD is assumed to reduce methane (CH4) emissions by an average of 48% compared to continuous flooding. Combining AWD with nitrogen-use efficiency and management of organic inputs can further reduce greenhouse gas emissions. This set of practices can be referred to as AWD+.

### 2. Increased net return for farmers

"Safe" AWD does not reduce yields when compared to continuous flooding, AWD in fact increase yields by promoting more effective tillering and stronger root growth of rice plants. Farmers who use pump irrigation can save money on irrigation costs and see a higher net return by using AWD. AWD may reduce labor costs by improving field conditions (soil stability) at harvest, allowing for mechanical harvesting.

## Where can AWD be practiced?

In general, lowland rice - growing areas where soils can be drained in 5-day intervals are suitable for AWD. High rainfall may impede AWD. If rainfall exceeds water lost to evapotranspiration and seepage, the field will be unable to dry during the rice growing period. Farmers must have control over irrigation of their fields and know that they will have access to water once fields have drained. AWD in rainfed rice is not recommended due to uncertain water availability when fields have to be reflooded.

## Mitigation potential of AWD

Flooded rice systems (comprising irrigated, rainfed, and deepwater rice) emit significant amounts of $CH_4$. Although estimates vary and have high uncertainty, recent work suggests that flooded rice contributes about 10 - 12% of anthropogenic emissions from the agriculture sector. Water regime and organic inputs are the primary determinants of $CH_4$ emissions in rice systems but soil type, weather/climate, tillage management, residue, fertilizers, and rice cultivars also play a role. Research has consistently found that noncontinuous water regimes such as AWD produce significantly lower $CH_4$ emissions than continuous flooding. According to empirical models, 15–20% of the benefit gained by decreasing $CH_4$ emission is offset by the increase in $N_2O$ emissions. However, net GWP is still significantly lower under AWD than in continuously flooded fields. The mitigation potential of AWD depends strongly on its proper execution. Incomplete drainage (not allowing the water table to drop to 15 cm below soil surface) can result in negligible reductions in GHG emissions.

Using IPCC 2006 guidelines, it has been estimated that if all continuously flooded rice fields were drained at least once during the growing season, global $CH_4$ emissions would be reduced by 4.1 Mt per year. Emissions models estimate that application of rice straw in the fallow period instead of soil incorporation directly during puddling would further significantly reduce $CH_4$ emissions.

## How does AWD reduce GHG emissions?

$CH_4$ in wet or "paddy" rice soil is produced by the anaerobic decomposition of organic material after the flooding of rice fields. Allowing the field to drain removes the anaerobic condition for a time and halts the production of $CH_4$, thus reducing the total quantity of $CH_4$ released during the growing season. The production of $N_2O$ is also regulated by the presence of oxygen. In contrast to $CH_4$ however, the recurring shift between aerobic and anaerobic conditions favors bacterial conversion of other nitrogen compounds to $N_2O$ and its release from the soil. The production of $N_2O$ is also strongly influenced by the availability of nitrogen in the soil. Thus, $N_2O$ emissions increase with the amount of nitrogen fertilizer applied to rice paddies.

The feasibility of this practice depends on the cropping calendar, as in some areas fields are also irrigated during the dry season, leaving little time for aerobic decomposition of organic inputs. Straw and manure, which can also be composted, emit less $CH_4$ than fresh organic material once applied to rice soils. Ideally, management of organic residue includes biogas technology. Biogas ($CH_4$) produced from rice straw reduces fossil fuel consumption. The remaining biogas slurry represents a good form of fertilizer with low $CH_4$ emission potential, compared with soil application of fresh organic material.

## Crop Water Requirement for Effective On-Farm Water Use Efficiency

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The crop water need (ET crop) is defined as the depth (or amount) of water needed to meet the water loss through evapotranspiration. In other words, it is the amount of water needed by the various crops to grow optimally.

The crop water need always refers to a crop grown under optimal conditions, i.e. a uniform crop, actively growing, completely shading the ground, free of diseases, and favourable soil conditions (including fertility and water). The crop thus reaches its full production potential under the given environment.

The crop water need mainly depends on:

- The climate: in a sunny and hot climate crops need more water per day than in a cloudy and cool climate
- The crop type: crops like maize or sugarcane need more water than crops like millet or sorghum
- The growth stage of the crop; fully grown crops need more water than crops that have just been planted.

## Influence of climate on crop water needs (ETo)

The major climatic factors which influence the crop water needs are:
- sunshine, temperature, humidity, wind speed

**Effect of major climatic factors on crop water needs**

| Climatic Factor | Crop water need | |
|---|---|---|
| | High | Low |
| Temperature | hot | cool |
| Humidity | low (dry) | high (humid) |
| Wind speed | windy | little wind |
| Sunshine | sunny (no clouds) | cloudy (no sun) |

The highest crop water needs are thus found in areas which are hot, dry, windy and sunny. The lowest values are found when it is cool, humid and cloudy with little or no wind.

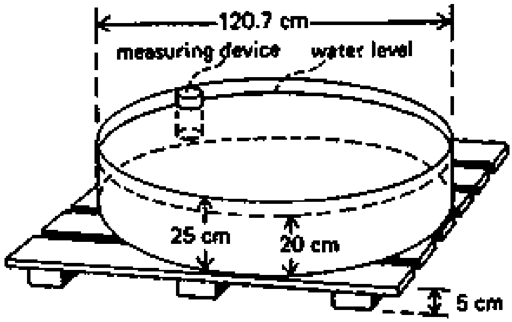
The influence of the climate on crop water needs is given by the reference crop evapotranspiration (ETo). The ETo is usually expressed in millimetres per unit of time, e.g. mm/day, mm/month, or mm/season. Grass has been taken as the reference crop.


There are several methods to determine the ETo.

## Pan Evaporation Method

Evaporation pans provide a measurement of the combined effect of temperature, humidity, wind speed and sunshine on the reference crop evapotranspiration ETo. Many different types of evaporation pans are being used. The best known pans are the Class A evaporation pan (circular pan) and the Sunken Colorado pan (square pan)

## Class A evaporation pan




The principle of the evaporation pan is the following:

- The pan is installed in the field. The pan is filled with a known quantity of water (the surface area of the pan is known and the water depth is measured). The water is allowed to evaporate during a certain period of time (usually 24 hours). For example, each morning at 7 o'clock a measurement is taken. The rainfall, if any, is measured simultaneously after 24 hours, the remaining quantity of water (i.e. water depth) is measured. The amount of evaporation per time unit (the difference between the two measured water depths) is calculated; this is the pan evaporation: E pan (in mm/24 hours). The E pan is multiplied by a pan coefficient, K pan, to obtain the ETo.

**Formula: ETo = K pan × E pan**

If the water depth in the pan drops too much (due to lack of rain), water is added and the water depth is measured before and after the water is added. If the water level rises too much (due to rain) water is taken out of the pan and the water depths before and after are measured.

**For the Class A evaporation pan, the K pan varies between 0.35 and 0.85. Average K pan = 0.70.**
**For the Sunken Colorado pan, the K pan varies between 0.45 and 1.10. Average K pan = 0.80.**

## Details of the pan coefficient are usually provided by the supplier of the pan.

Formulation of the Penman-Monteith equation

In 1948, Penman combined the energy balance with the mass transfer method and derived an equation to compute the evaporation from an open water surface from standard climatological records of sunshine, temperature, humidity and wind speed. This so-called combination method was further developed by many researchers and extended to cropped surfaces by introducing resistance factors.

The resistance nomenclature distinguishes between aerodynamic resistance and surface resistance factors. The surface resistance parameters are often combined into one parameter, the 'bulk' surface resistance parameter which operates in series with the aerodynamic resistance. The surface resistance, $r_s$, describes the resistance of vapour flow through stomata openings, total leaf area and soil surface. The aerodynamic resistance, $r_a$, describes the resistance from the vegetation upward and involves friction from air flowing over vegetative surfaces. Although the exchange process in a vegetation layer is too complex to be fully described by the two resistance factors, good correlations can be obtained between measured and calculated evapotranspiration rates, especially for a uniform grass reference surface.

## FAO Penman-Monteith equation

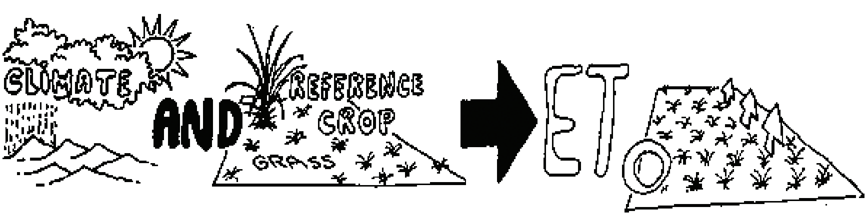
From the original Penman-Monteith equation and the equations of the aerodynamic and surface resistance the FAO Penman-Monteith method to estimate $ET_o$ can be derived:

$$\boxed{ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}}$$

where $ET_o$ reference evapotranspiration [mm day$^{-1}$], $R_n$ net radiation at the crop surface [MJ m$^{-2}$ day$^{-1}$], G soil heat flux density [MJ m$^{-2}$ day$^{-1}$], T mean daily air temperature at 2 m height [°C], $u_2$ wind speed at 2 m height [m s$^{-1}$], $e_s$ saturation vapour pressure [kPa], $e_a$ actual vapour pressure [kPa], $e_s$-$e_a$ saturation vapour pressure deficit [kPa], D slope vapour pressure curve [kPa °C$^{-1}$], g psychrometric constant [kPa °C$^{-1}$].

The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water.

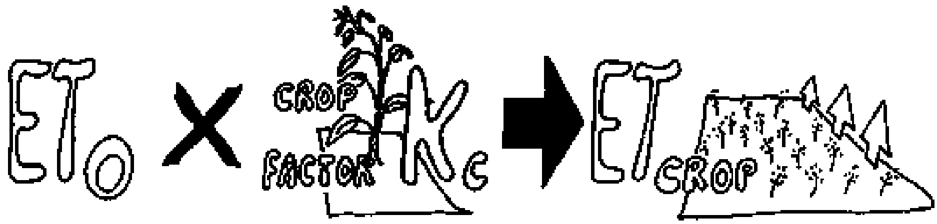
## Influence of crop type on crop water needs (Kc)



The relationship between the reference grass crop and the crop actually grown is given by the **crop factor,** Kc, as shown in the following formula:

$$\boxed{\mathbf{ETo \times Kc = ET\ crop}}$$

Both ET crop and ETo are expressed in the same unit: usually in mm/day (as an average for a period of one month) or in mm/month.

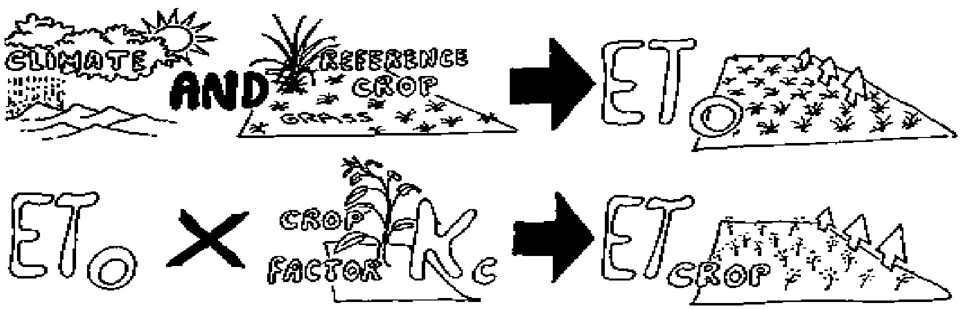



The crop factor, Kc, mainly depends on: the type of crop, the growth stage of the crop, the climate

Thus, to determine the crop factor Kc, it is necessary, for each crop, to know the total length of the growing season and the lengths of the various growth stages.

Per crop, **four** crop factors have to be determined: one crop factor for each of the **four** growth stages.

**Calculation of the crop water need**



# 40. Water Management in Irrigated Dry Crops

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Water is one of the most important inputs essential for the production of crops. It profoundly influences photosynthesis, respiration, absorption, translocation and utilization of mineral nutrients, and cell division besides some other processes. Both its shortage and excess affect the growth and development of a plant directly and, consequently, its yield and quality. Its frequency distribution and amount are not in accordance with the needs of the crops. Water is a costly input when canals supply it. The constructing of dams and reservoirs, the conveying of water from storage points to the fields, the operating and the maintaining of canal systems involve huge expense. The misuse of water leads to the problems of water logging, salt imbalance, etc. thus rendering agricultural lands unproductive. Hence a proper appreciation of the relationship and economic utilization of water resources for maximum crop production.

The main challenge confronting water management in agriculture is to improve water use efficiency and its sustainability. This can be achieved through (i) an increase in crop water productivity (an increased in marketable crop yield per unit of water transpired) through irrigation, (ii) a decrease in water losses through soil evaporation that could otherwise be used by plants for their growth, and (iii) an increase in soil water storage within the plant rooting zone through better soil and water management practices at farm ( like using right irrigation method like ridge and furrow method, and micro irrigation (Drip & sprinkler methods)and area-wide (catchment) scales.

The term "irrigated dry crops" or "ID crops" refers to those crops which, unlike paddy, do not require wetland or standing water conditions for their cultivation. The root zone of ID crops should contain balanced amounts of soil-water and air to ensure good crop growth. Paucity of soil-water or an excess of it in the root zone is harmful to these crops. To regulate the soil-water balance in the root zone for better plant growth and production, ID crops need to be irrigated periodically or at suitable-intervals.

## Quantum of Water Required by Plants

Water requirement of a crop is the quantity of water needed for normal growth, development and yield and may be supplied by precipitation or by irrigation or by both. Water is needed mainly to meet the demands of evaporation (E), transpiration (T) and metabolic needs of the plants. The water requirement of any crop is dependent upon,

- Crop factors like variety, growth stage, duration, plant population and growing season.

- Soil factors like texture, structure, depth, and topography.
- Climatic factors like temperature, relative humidity and wind velocity.
- Crop management practices like tillage, fertilization, weeding etc.

Irrigation scheduling is important in water management of ID crops. Scientific irrigation scheduling is a technique providing knowledge on correct time and optimum quantity of water application at each irrigation to optimize crop yields with maximum water use efficiency and at the same time ensuring minimum damage to soil properties. Crops vary with their soil moisture requirement for maximum yields and quality of produce. By knowing the amount of moisture available in the root zone of the crop and the evapotranspiration demands of the crop and atmosphere, it is easy to determine when irrigation is needed. There are several approaches to decide 'when to irrigate' based on soil, plant and atmospheric parameters, combination of soil and atmospheric parameters and critical crop stage approaches.

## Factors to be considered while Scheduling Irrigation

1. Soil, 2. Soil- Water Relationships, 3. Crops and its stage, 4. Sensitivity to drought Stress, 5. Climate (rainfall & temperature), 6. Water supply, 7.Flexibility and performance of irrigation System, 8. System layout, Socio-economic factors

Ideally, the irrigation depth and the irrigation interval depend mainly on soil type, climatic conditions, type of crop and with the stage of growth of the crop. At the beginning of the growing season the depth of irrigation is kept low, but the applications are frequent. This is due to the low value of ETc of the growing seedling and their shallow root system. During the mid-growth stage of the crop the depth of irrigation is increased and irrigations are given less frequently. Controlling irrigation depths is not difficult under sprinkler and drip methods of irrigation. However, with surface irrigation methods the scope for changing irrigation depths is limited. The amount of effective rainfall which may occur during the crop season is deducted from the amount of irrigation water estimated to be applied in the irrigation which follows. Alternatively, provision may be made to allow for the precipitation which is expected during the crop growing period.

## Techniques of Irrigation Scheduling

### Soil moisture regime approaches

In these methods, soil moisture content is estimated to know the deficit in available soil moisture as which it is proposed to irrigate based on predetermined soil moisture content to bring the soil to field capacity. Soil moisture content is estimated either by direct gravimetric method or indirect measurements such as tensiometers, resistance blocks, neutron probe etc. Soil moisture content can be judged by feel and appearance of the soil by experience.

## Plant indices

Any plant character related directly or indirectly to plant water deficit which responds readily to integrated influence of soil, water, plant and evaporative demand of the atmosphere may serve as a criterion for timing of irrigation to crop.

a. **Visual plant symptoms:** Visual signs of plants wilting can be used to schedule crop irrigation. Farmers frequently use dropping, curling and rolling of sensitive plant parts as an indication for plant water deficit.

b. **Increased plant stand:** An area of about 1.0m2 , preferably in a high spot, is sown with the same crop to maintain about four times the plant population compared with that in the surrounding area. Crop with high stand establishment wilts earlier than the crop in the rest of the field indicating timing of irrigation.

**Critical growth stages:** The growth period of irrigated dry (ID) crops can generally be divided into 3 phases namely 1.Vegetative, 2. Reproductive and 3. Ripening phases.

- **Vegetative phase:** The early vegetative phase consists of crop establishment or initial stage during the first 2 - 3 weeks after sowing. This is followed by crop development stage which last for 2 - 6 weeks in different crops.
- **Reproductive or flowering phase:** The reproductive or flowering phase comprises the period from initiation of buds to 75% flowering. This period in most of the seasonal ID crops last for 2 - 3 weeks and in two seasonal crops and perennial crops for 4 - 6 weeks or more.
- **Yield formation stage/ripening phase:** In this phase the end product is formed. The flowering and yield formation period together is known as mid-season stage. During the last part of the ripening phase the crops undergo yellowing and drying to mature. This period is called maturity stage or late season stage and it last for 2 - 4 weeks in most crops.
- The entire reproductive phase is highly sensitive growth period when the growth rhythm is fast. Therefore the soil water stress should be avoided during this period. Active vegetative phase and yield formation stage are moderate in sensitivity while initial establishment and maturity stages are least sensitive to water stress.
- Some crops like Cotton, Groundnut and pulses even prefer stress during early vegetative growth to suppress excessive vegetative growth. In many crops the initial establishment and flowering stages are highly sensitive to excess water conditions resulting in poor performance of the root system and also shedding of flowers, in addition to lodging at maturity in some crops.

Relative leaf water content, plant water potential, stomatal resistance and plant temperature which can adequately reflect the internal water balance of the plant may be used as potential indicators for scheduling crop irrigation.

## Climatological approach

Potential rate of water loss from a crop is primarily related to evaporative demand of the atmosphere. Irrigation can be scheduled if allowable depletion of moisture in the root zone and evapotranspiration during the crop period is known. Pan evaporation is used to determine the amount of irrigation water to be applied in the ratio of irrigation water (IW) and cumulative pan evaporation (CPE) from USWB class A pan, usually known as IW/CPE ratio method. IW/CPE ratio of 1.0 indicates scheduling irrigation with quantity of irrigation water equal to that lost in evaporation.

## Profile modification

This method also known as soil cum sand mini plot technique is used for timing irrigation to crops. The principle involved is to reduce artificially, the available water holding capacity of soil in root zone depth in mini plot by mixing sand with it. Usually a pit of 1.0 cu.m is excavated and each layer is mixed with 5% by volume of sand and the pit refilled by compacting each layer to bring bulk density of soil in the mini plot as that of the surrounding area. Symptoms of plants in the mini plot indicate time for irrigating the crop.

## Depth of Irrigation

The quantity of irrigation water applied should bring the soil to field capacity. The quantity of water to be applied to the soil at each irrigation depends on i). The amount of available soil moisture (ASM) in the effective root depth at the start of the irrigation or the level of available soil moisture depletion (DASM) considered for irrigation, ii). Effective rainfall and ground water contribution during the interval between two irrigations, iii). Additional quantity of irrigation water if any, required to leach the soils beyond the root zone depth and iv). The application losses.

# 41. Water Management is the Key for Sustainable Development

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Water is one of the important requirements for human life & it is the Nature's free gift to human race. The use of water by man, plants and animals is universal. Water plays important role in the agriculture, manufacture of essential commodities, generation of electricity, transportation recreation, industrial activities, etc. But to ensure their services for all the time to come, it becomes necessary to maintain, conserve and use these resources very carefully in every sphere of life. Although water is the most widely occurring substance on Earth, only 2.53% of it is fresh water and the remaining 97.47% is saltwater. Of the small amount of freshwater, only one third is easily available for human consumption, the large majority being locked up in glaciers' and snow cover.

## Water Crisis:

Water crisis is the one that lies at the heart of our survival, and that of our planet earth. As all different modes of water use have continued to increase, many countries, especially those located in arid and semi arid regions have started to face crises, although the magnitude, intensity and extent of the crisis could vary from country to another or even within the same country, and also over time. There are many, often interrelated, factors that could make the water crisis more pervasive in different parts of the world in the coming years. Increasing population and higher levels of human activities, including effluent disposals to surface and ground water sources, have made sustainable management of water resources a very complex task throughout the world. In addition, per capita demand for water in most countries is steadily increasing as more and more people achieve higher standards of living and as lifestyles are changing rapidly.

## Water Scarcity:

UNESCO has defined water scarcity based on the per capita availability of usable water as

Below 1,700 $m^3$ per capita/year : Water scarce

Less than 1,000 $m^3$ per capita/year : Severely water scarce

**Status** : 1990: 18 severely scarce countries (12 less than 500 $m^3$),

2025: 30 severely scarce countries (19 less than 500 $m^3$)

When country's renewable water supplies drop below about 1700 cubic meters per capita, it becomes difficult for that country to mobilize enough water to satisfy all the food, household, and industrial needs of its population. Countries in this situation typically begin to import grain, reserving their water for household and industrial use. At present, 34 countries in Asia, Africa, and Middle East are classified as water stressed, and all but two of them – South Africa and Syria are net importers of grain. Collectively, these water stressed countries import nearly 50 million tons of grain a year. By 2025, the number of people living in water stressed countries is projected to climb from 470 million to 3 billion – more than six fold increase.

## Water Usage:

Water is essential to life in every way, we need clean water for drinking, adequate water for sanitation and hygiene, sufficient water for food and industrial production, and much of our energy generation relies on or affects water supplies. Demographic and urban growth over the next century will mean a far greater demand for water for industrial production. Water usage pattern which is growing at alarming rate is shown in the table:

**Comparison of water usage in different sectors**

| Sector | Usage in (%) | | | |
|---|---|---|---|---|
| | World | Europe | Africa | India |
| Agriculture | 69 | 33 | 88 | 82 |
| Industry & others | 23 | 54 | 5 | 12 |
| Domestic use | 8 | 13 | 7 | 6 |

## Water for Agriculture:

Almost 70% of all available freshwater is used for agriculture. Over pumping of ground water by the world's farmers exceeds natural replenishment by at least 160 billion cubic meters a year. It takes an enormous amount of water to produce crops: three cubic meters to yield just one kilo of rice. Land in agricultural use has increased by 12% since the 1960s to about 1.5 billion hectares. Current global water withdrawals for irrigation are estimated at about 2,000 to 2,555 $km^3$ per year.

Agriculture is responsible for most of the depletion of ground water, along with up to 70% of the pollution. Both are accelerating. Many of the world's most important grain lands are consuming ground water at unsustainable rates. For the last half-century, agriculture's principal challenge has been raising land productivity – getting more crops out of each hectare of land. As we have stepped into the twenty first century, the new frontier is boosting water productivity getting more from every litre of water devoted to crop production.

The key is to custom design strategies to fit the farming culture, climate, hydrology, crop choice, water use pattern, environmental conditions, and other characteristics of each particular area. Drip irrigation ranks near the top of measures with substantial untapped potential. In contrast to a flooded field, which allow a large share of water to evaporate without benefitting a crop, drip irrigation results in negligible evaporation losses. When combined with soil moisture monitoring or other ways of assessing crop's water needs accurately, drip irrigation can achieve efficiencies as high as 95 per cent, compared with 50-70% for more conventional flood or furrow irrigation.

## Water Footprint:

Water Footprint is quite simply the volume of water used. At the individual level, this is expressed in litres. But at the national level, this becomes complex – The water footprint of a Nation is equal to the use of domestic water resources, minus the virtual water export flows, plus the virtual water import flows.

The total 'water footprint' of a Nation is a useful indicator of a Nation's call on the global water resources. The water footprint of a Nation is related to dietary habits of people. High consumption of meat brings along a large water footprint. Also the more food originates from irrigated land, the large is the water footprint. Finally, Nations in warm climate zones have relatively high water consumption for their domestic food production resulting in a larger water footprint. At an individual level, it is useful to show the footprint as a function of food diet and consumption patterns.

## Virtual Water:

The concept of virtual water emerged in the early 1990s and was first defined by Professor J.A. Allan as the water embedded in commodities. Producing goods and services requires water; the water used to produce agricultural or industrial products is called the virtual water of the product. Virtual water is an essential tool in calculating the real water use of a country, or its water footprint, which is equal to the total domestic use, plus the virtual water import, minus the virtual water export of a country. At the individual level, the water footprint is equal to the total virtual water content of all products consumed.

## Adopting a virtual water strategy:

Improving of virtual water (via food or industrial products) can be a valuable solution to water scarcity, especially for arid countries that depend on irrigation to grow low-value food with high water needs. Already a number of countries, such as Israel and Jordan, have formulated policies to reduce export of water-intensive products. Currently, 60 to 90% of Jordan's domestic water is imported through virtual water.

## Sustainable Development:

The World Commission on Development (known as Brundtland Commission) in 1987 coined a term 'Sustainable Development' defined as 'Development that meets the need of the present without compromising the ability of the future generations to meet their own needs'.

International Conference on Water and Environment (ICWE) held in Ireland in 1992 has made the following recommendations (Dublin Principles) indicating the importance of water for sustainable development.

1. Freshwater is a finite vulnerable resource, essential to sustain life, development and environment.
2. Water development and management should be based on a participatory approach involving users, planners and policy makers at all levels.
3. Women play a central part in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

## Conclusions

The world and more importantly the developing countries are heading towards water stress and scarcity. They are left with no alternative but to adopt modern irrigation technologies, which save water, double the area under irrigation, improve yields and quality as well as save on labour, energy and crop production costs. There is necessity to undertake large-scale micro irrigation projects to bring more areas under drip irrigation systems improving water use efficiencies to as high as 95%.

# 42. Extension Strategies for Promoting Climate Smart Agriculture

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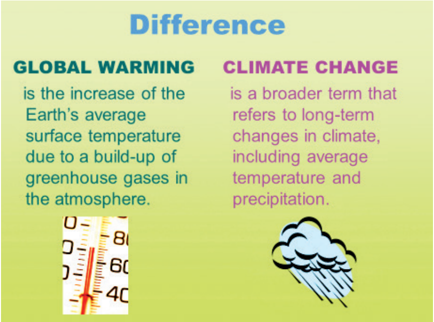
According to IPCC, Climate change as defined by Intergovernmental Panel on Climate Change (IPCC) "refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer"




**Box -1: Important concepts**

**VULNERABILITY TO CLIMATE CHANGE:** Is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is EXPOSED, it's SENSITIVITY, and it's ADAPTIVE CAPACITY.

**VULNERABILITY = function [exposure (+); sensitivity (+); adaptive capacity (-)]**

**VULNERABILITY = potential impact (sensitivity x exposure) – adaptive capacity**

**EXPOSURE :** The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.

**SENSITIVITY:** The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea level rise).

**POTENTIAL IMPACT:** Impacts of climate change are the effects of climate change on natural (e.g. water resources, biodiversity, soil, etc) and human systems (e.g. agriculture, health, tourism, etc). Potential impacts are all impacts that may occur given a projected change in climate, without considering adaptation.

**ADAPTIVE CAPACITY:** The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantages of opportunities, or to cope with the consequences.

**Source: Adopted from IPCC**

Climate change is now accepted as real, pressing and global problem by both scientific and public alike. Recognizing the change in climate has led multilateral negotiations across the globe to minimise or negate the impacts of climate change on the biosphere. Studies show that climate change has conspicuous impacts on hydrology, cryosphere, meteorology, lithology, topography, etc. as a result, the entire, sectors *viz.*, primary (mining, fishing, agriculture etc), secondary (oil refinery, manufacturing, food processing etc.) and tertiary(financial, education, banking, etc.) have incurred a loss. Of the three sectors, primary that too, agriculture is considered a climate-sensitive sector. Several perceptions and opinion studies held by a range of scientific and academician cite that the communities across the globe perceive that the climate has changed. Thus, the chapter on climate change elucidates the impacts of climate change on agriculture and explicitly discusses the mitigation and adaptation/ extension advisory services within the framework of climate smart agriculture or climate smart villages.

## Climate change – Overview

Climate change alters the production systems, thereby threatens the food security of the billions of population across the globe. Weather is the single largest source of variability that affects farm output drastically. About 20-80% of the inter-annual variability occurs due to variability in weather parameters. Thechanges in weather bring either direct physiological stress in the crops or indirect pest and diseases or both (PIB, 2019). Further, the climate change would be a threat to the livelihood of 36% or 2.6 million of the global population, because the income source of these is directly dependent on agriculture and allied activities (Dickie *et al,* 2014 and Pareek, 2017). The change in climate is conspicuous due to the visibility in the increase in atmospheric $CO_2$ concentration. The conditions of livelihood will even get worse in the regions like Asia &Pacific and Africa as about 40-50% and 67% of the total population of these regions are directly working in agriculture. The increase in global temperature is the root cause of climate change and it is caused by the two major factors namely climate itself and anthropogenic activities.

## Climate change – contributing factors

Greenhouse gases ($CO^2$, $CH_4$ and $N_2O$) on the atmosphere and their variations are the cause of climate change. India's share of GHG emission to the total emission of the world is about 6.55%, thereby becoming the third largest GHG emitter in the world (Sapkota *et al.,* 2019). Both natural and anthropogenic activities are contributed to the emission of GHG worldwide. Burning of fossil fuel, transportation, deforestation is attributed to the man-induced influences on climate change. In India, the sectors such as Energy, Agriculture, Industrial process, land use management and wastes release about 68.7%, 19.6%, 6%, 3.8% and 1.9% of Green House Gases (GHG) respectively to the climate change. Of the 19.6% of the Green House Gas emitted from the agricultural sector, about 47% and 45% of the gases are released from the use of synthetic fertilisers and enteric fermentation, respectively (WRI CAIT, 2017 as cited in USAID). Cattle production is the most important factor in the GHG emission, followed by rice cultivation, buffalo, small ruminant and wheat production. Of the total crops cultivated in India, over 52% of the GHG emission is from rice cultivation, followed by wheat, cotton and sugarcane, thus, these crops contributed about 80% of the total GHG emissions of the total agricultural crops. In the livestock sector, cattle, buffalo, sheep and goat has contributed about 99% of the GHG emission. The report of WRI CAIT shows that the agriculture emission of GHG increased by 25% from 1990 to 2014. According to the parliamentary committee report, From 1970 to 2014, greenhouse gas emissions increased by 80%; 33 lakh tonnes of methane is released by paddy fields and 0.5-2 kg nitrous oxide is released per hectare (of paddy fields) (Mishra, 2019). The release of $CO_2$, Methane and Nitrous Oxide etc. are the primary causal agents of global climate change. Agriculture plays a dual role in climate change both as a contributor to climate change and also mitigate the impacts of climate change through carbon sequestration. The cultivation of rice is responsible for the release of global warming gases such as $CH_4$ and $N_2O$ coupled with burning of straw aggravates the warming of the earth. About 80% of straw is burned in India, especially after combined harvesting. The burning results in loss of soil nutrients such as N, $P_2O_5$, and $K_2O$. In Punjab, paddy straw/residue burning caused a net loss of 4.5 billion INR (Gupta *et al.,* 2004). Moreover, the excessive de-vegetation, industrialisation, increasing pollution, use of chemical and fertilisers are significantly contributing to climate change (Rama Rao *et al.,* 2018).

**Table 1: Highest GHG emitting state crop wise**

| S. No. | Crop wise GHG emission | Highest emitting State |
|---|---|---|
| 1. | Rice | Andhra Pradesh |
| 2. | Wheat | Uttar Pradesh |
| 3. | Sugarcane | Maharashtra |
| 4. | Cotton | Uttar Pradesh |
| 5. | Buffalo | Uttar Pradesh |
| 6. | Cattle | Madhya Pradesh |
| 7. | Goats and sheep | Andhra Pradesh |

*Source: Sapkota et al., 2019*

## Impacts of climate change – Indian Experience

In total, about 800 million people in South Asia would be prone to climate change scenario including India. GDP per capita in India is estimated to decline to 9.8% by 2050 under carbon intense climate change, further, India may have to face a loss of 2.5% GDP by 2050 due to climate change. Similarly, the climate change induced yield loss was estimated to be 4.5 to 9% in India, which will lead to a loss of 1.5% of GDP on an annual basis (Vijayan and Viswanathan, 2018). In India, central region states such as Chhattisgarh and Madhya Pradesh in a northern state like Uttar Pradesh, and northwestern regions like Rajasthan were identified to be more vulnerable to change in average weather parameter, thereby affecting agriculture, health and overall living standards of the population (World Bank, 2018). In India, the loss of productivity and increase in food price are the two extremities of climate change, which could push about 42 million population additionally into the poverty trap and cause 0.4% loss in overall consumption rates. India is likely to face around 10% rise in cereal price and 3-4% more poverty after 30 years than the present times due to rise in temperature and other weather parameters (Jacoby *et al.,* 2011). Indian farmers might have to incur near about 3% net income loss if the temperature rises by 2°C and +7% change in average precipitation (Kumar, 2011). Climate change may cost USD 9 to 10 billion every year. India might have to produce 70 million more food grains by 2030 to feed the growing population (The economic times, 2017).

## Recent observations on climate change and its impact on agriculture

The impact of climate change on the land mass/biosphere is invariably linked to the production systems of crops. As the land is the pool house of Carbon, it can play a major role in the carbon cycle and increasing the crop yield. Climate has strong influences on soil formation, development and its use. However, the chemical and physical properties of soil have been altering due to changes such as rise in temperature, variations in rainfall, increased evapotranspiration, drought, loss in Organic Matter Content, chronic loss in water holding capacity and nutrition availability. Therefore, affecting the growth and development of crops.These changes will lead to fluctuation in organic matter turnover and $CO_2$ cycle (Karmakar *et al.,* 2016).

## Temperature

The mean global temperature (combined land and ocean surface) was about 0.85°C between 1880 and 2012 (IPCC). The global yield of wheat, rice, maize and Soybean will be reduced by 6%, 3.2%, 7.1% and 3.1% for every 1°C increase in mean temperature. The annual mean temperature in India rises by 0.68°C in every 100 years and India is continued to witness increased post-monsoon and winter warning (Kaur and Kaur, 2018). It is projected that temperature would rise to 2-4°C in Southern India i.e. regions south of 25N° and 4°C in the northern regions (Kumar, 2011).

**Box - 2: Crop productivity in India**

A 1°C increase in temperature would cause yield loss of about 3 to 7% in wheat, soybean, mustard, groundnut, and potato. The productivity of major crops will further see a 10 to 40 loss due to rise in temperature, rainfall variability, and decrease in irrigation water by 2100. Wheat growth in India could be affected under increasing temperature i.e. more than 34°C (Lobell, Sibley, & Ortiz-Monasterio, 2012)

India is likely to see 15-17% food grain reduction for every 2°C increase in temperature. In Rajasthan, the yield of Pearl Millet would be reduced to 10-15% at the 2°C increase in temperature and in Madhya Pradesh, Soybean yield is expected to decline by 5% for about 2°C increase in temperature. Therefore, the 2°C increase in temperature might reduce the rice yield by 0.75 tonnes per ha. Similarly, increase temperature about 0.5°C in winter may reduce wheat yield by 0.45 tonnes per ha (cited by Kaur and Kaur, 2018 and IPCC, 2007). The increasing temperature produces more heat stress to the crops. Yet, the magnitude of effects differs across the latitudes. For example, a 2°C increase in temperature in the mid-latitudewould increase wheat production by 10%. The heat and cold waves are the other extremities of the rising and decreasing temperatures in the tropical and sub-tropical/temperate regions respectively. These waves are also a cause for a significant loss of crop production across the country, yet the magnitude of loss is lesser when compared to other climate extremities such as drought and flood. Moreover, the cold waves are the phenomena in the winter season across the length of the country.

**Box-3: Impacts felt everywhere**

About 50% of the farmers in Mahbubnagar district in the state of Telangana opined that the rate of unemployment has become severe during drought seasons. The severity of drought further forces the farmers to mortgage their productive lands to meet the basic needs. In the same way, farmers have been facing detrimental challenge to the education of children, food for self-consumption and socio economic support system as a result of emerging water disputes, out migration, etc.

Singh ***et al.,*** 2017

## Drought

Drought occurs from acute water shortage resulting from subnormal rainfall, erratic and uneven distribution rainfall coupled with ever-increasing temperature. IMD defines drought as a year or season in which the total rainfall is less than 75% of the climatological norm (or 30-year average).

**Box-4: A case of Marathwada Region – frequency of droughts**

Marathwada region in Maharashtra state of India is vulnerable to climate extremities such as dry weather, deficient rainfall etc. During 2011 to 2015, the Marathwada region faced a total of 4 deficit rainfall years. The year 2011, 2012, 2014 and 2015 received a deficient rainfall of about 19% (667.5 mm), 23% (637.2 mm), 46% (448.3 mm) and 59% (336.7 mm) respectively against the normal rainfall (830.3 mm). The data show that, every year the rainfall pattern deviates from its normal pattern as well as the year 2015 was recorded to be the prolonged dry spell, which lasted for more than 45 days. This resulted in severe droughts across the Marathwads regions. These dry spells affected the crops such as Soy beans, Pigeon Peas and a subsequent moisture stress had a negative effect on pod size, vegetative stages, and overall yield.

***-Asewar et al., 2018***

During 19000-2014, a large number of the Indian population have affected from drought, which was higher for any other natural disaster. Successful cultivation of crops is dependent on the nature of drought (chronic and contingent), its duration, frequency of occurrence within the season (Rao *et al,* 2016). Droughts can cause long term water shortage and heat stress to the crops, thereby affecting the yield (Conforti *et al.,* 2017). A total of 38% of the world area is exposed to droughts, which would impact the 70 of the agricultural output (Dilley *et al,* 2005). About 83% of the loss caused by droughts was accrued to the agriculture sector during 2006-2016 (Conforti *et al.,* 2017).

In India, failure of monsoon or reduction in rainfall leads to drought or drought-like conditions, which causes 18% yield loss in unirrigated conditions (Economic Survey, 2017). About 60 of Indian districts were considered to be the most drought-prone and have less resilient areas. Only 10 states out of 30 states and UTs have at least 50% resilient areas, the lower Himalayan region states such as Sikkim, Punjab, Haryana, Uttarakhand, Himachal Pradesh and Arunachal Pradesh have more resilient areas. Whereas, the states Karnataka and Kerala had less resilient areas. It is observed that the states with more forest areas/cover can exhibit more resilience than the states with other types of Biomass (Sharma and Goyal, 2018).

**Table 2: Frequency of occurrence of drought in India region wise**

| S. No. | Regions | Frequency of occurrence of drought |
|---|---|---|
| 1. | Assam | Very rare once in 15 years |
| 2. | West Bengal, Mandya Pradesh, Konkan, Bihar, and Odisha | Once in 5 years |
| 3. | South Interior Karnataka, Eastern Uttar Pradesh, and Vidarbha regions of Maharashtra | Once in 4 years |
| 4. | Gujarat, East Rajasthan, and Western Uttar Pradesh | Once in 3 years |
| 5. | Tamil Nadu, Jammu and Kashmir and Telangana | Once in 2.5 years |
| 6. | Western Rajasthan | Once in 2 years |

*Source: NRAA, 2013*

## Cold Waves

The cold waves in extreme cases could reduce the crop yield by 10-40% in wheat, 10-15% in winter rice, 25-30% in pulses, 50-70% in mustard seed 60-95% in amla (Samra *et al.,* 2003). Importantly, pollen sterility is the major cause of the cold waves, thereby reducing the yield of crops to a greater extent.

## Rainfall

In India, *Kharif* and *Rabi* seasonal rainfall have reduced by 26 and 33 mm respectively between 1970 and 2015 (Economic Survey, 2017-18), meanwhile, annual rainfall was reduced by 86 mm in the same time period. The economic survey shows that the proportion of wet (rainfall more than 80 mm per day) and dry days (rainfall less than 0.1 mm/day) has become intensified between 1970 and 2015. About 15-40% reduction in rainfall may happen in northern regions (NATCOM, 2004). Besides, the increased intensity of rainfall during the monsoon season has resulted in a severe flood in many parts of India. Delayed and early withdrawal of monsoonis reported by the farmers in the north and south zones of India (Rama Rao *et al.,* 2018).

## Flood

About 23 of 36 States / Union Territories of the country are flood prone, i.e. about 49.8 Mha (15.2%) of lands are subjected to flood. 10-12 Mha of areas is flooded every year (Rao *et al.,* 2016). Flooding has caused the serious damage to the crops worldwide and it is a more calamitous disaster as the severity of damages can be observed in terms of damages to crops, water contamination, irrigation systems, livestock, other agricultural operations daily life etc. More than 50% and 40% of the farmers of East and North zones reported an increase in the frequency of flood in the recent past (Rama Rao *et al.,* 2018).The lower Ganga basin is susceptible to flooding, even a small variation in rainfall pattern would affect the yield of crops grown in that regions (Gornall *et al.,* 2010). During 1953-2010, the damages caused by the flood were estimated to be Rs. 8.12 trillion in India. Recently, in 2018, heavy downpour in Kerala state affected the entire state with the heavy flood and inundation. The "2018 flood" caused by the heavy downpour has been the worst flood since 1924. This flood took a high toll and estimated loss of 95, 000 million INR. The yield loss of Black pepper, cardamom, nutmeg, clove, ginger, turmeric was estimated to be about 25-55, 20-35, 15-25, 10-20, 15-25 and 10-15% respectively. The production loss of these crops was about 26 thousand tonnes during 2018-19, valuing about 12451.1 million INR (Thomas *et al.,* 2018).

**Table 3: Flood/heavy rain affected areas and damages in India (1953-2011)**

| S. No. | Particular | Unit | Average | Maximum damage | Year |
|---|---|---|---|---|---|
| 1. | Area affected | Mha | 7.2 | 17.5 | 1978 |
| 2. | Population affected | Million | 32.4 | 70.5 | 1978 |
| 3. | Crop area affected | Mha | 3.7 | 12.3 | 2005 |
| 4. | Value of damage of crops | Rs. In Million | 11.2 | 73.0 | 2003 |
| 5. | Value of total damage to crops and public utilities | Rs. in Million | 36.1 | 325.4 | 2009 |

*Source: Rama Rao et al., 2019*

## Water resources

The gross per capita availability of water is reducing on the account of two causes *viz.*, climate change and population growth (Schellnhuber *et al.,* 2013).The changes in precipitation, evapotranspiration and soil moisture under increasing temperature have a profound effect on water resources in particular groundwater resources (Singh and Kumar, 2014). Climate change induced changes in river flow and groundwater will have the serious of implications to the availability of irrigation water, thereby affecting millions of smallholders. India has only 1/25$^{th}$ of the water resource in the world whereas, every one in six the world population is Indian (Jat *et al.,* 2016). According to FAO, on an average 87% of water is used for agriculture in India. About 15% of the groundwater resources in India are damaged due to climate change. The more is the variability of rainfall, the more is the change in the groundwater levels (Singh and Kumar, n.d.). India has witnessed an 8 to 16 meters below ground level (mbgl) water depletion since 1980 (Zaveri *et al,* 2016). The effects of climate change in groundwater resources are seen in two ways *viz.*, imbalance in the distribution of groundwater recharge and change in the volume of groundwater recharge (Singh and Kumar, n.d.). The subsidised power supply to farmers is one of the major reasons that led to the rapid extraction of groundwater for irrigation and the conditions have become induced under the adversity of climate change (Zaveri *et al.,* 2016).

**Table 4: Expected Crop Water Requirement in Wheat by 2050**

| S. No. | State | Area (ha) | Crop water requirement (mm) | | | Water requirement (million cubic meter) | | | % Deviation (2020-1990) | % Deviation (2050-1990) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1990 | 2020 | 2050 | 1990 | 2020 | 2050 | | |
| 1. | **J&K** | 253023 | 217.4 | 224.3 | 229.7 | 823.9 | 851.7 | 874.5 | 3.1 | 5.3 |
| 2. | **HP** | 367770 | 281.8 | 291.8 | 299.1 | 1051.1 | 1089.7 | 1119.2 | 3.7 | 6.3 |
| 3. | **Punjab** | 3468000 | 359.1 | 371.8 | 380.8 | 12553.6 | 13002.5 | 13317.5 | 3.6 | 6.1 |
| 4. | **Haryana** | 2316674 | 452.1 | 467.1 | 480.9 | 10475.4 | 10825.4 | 11158.0 | 3.4 | 6.4 |
| 5. | **UP** | 9443104 | 423.7 | 434.6 | 447.9 | 39717.8 | 40750.1 | 41990.4 | 2.6 | 5.8 |
| 6. | **Bihar** | 2076727 | 438.6 | 449.3 | 465.0 | 9046.2 | 9271.1 | 9593.9 | 2.5 | 6.1 |
| 7. | **West Bengal** | 366729 | 399.8 | 407.2 | 425.2 | 1449.5 | 1479.8 | 1543.1 | 1.9 | 6.4 |
| 8. | **Rajasthan** | 2010241 | 485.3 | 498.6 | 511.6 | 9923.6 | 10208.4 | 10479.5 | 2.7 | 5.4 |
| 9. | **Gujarat** | 727400 | 604.7 | 614.7 | 630.9 | 4603.3 | 4683.2 | 4807.1 | 1.7 | 4.3 |
| 10. | **Madhya Pradesh** | 4188248 | 502.0 | 513.3 | 526.2 | 21176.9 | 21655.3 | 22200.1 | 2.3 | 4.9 |
| 11. | **Maharashtra** | 932800 | 606.417 | 617.82 | 633.5 | 5613.8 | 5718.3 | 5859.4 | 1.9 | 4.5 |

*Source: AICRPAM - CRIDA*

**Box- 5 : The water risks hot spots in India**

The states such as Punjab and Haryana account for about 15% of rice and 29% of wheat production in India (GoI, 2017). About 38 and 62% of rice and wheat are procured from these two states in the country (OECD/ICRIER, 2018). The factors such as abundant river water, groundwater, which coupled with fertile lands are contributing to the high crop productivity. However, in the recent past, the need for irrigation water for these two states has become intensified due to vagaries climate parameters like change in precipitation, high inter seasonal and inter annual rainfall pattern etc. as a result, the groundwater table has decreasing gradually. In 2010, the groundwater table in 75% of the Punjab state fell below 15 m as against 14% of the land mass of Punjab in 2000. Moreover, 51% and 75% of the local units of Haryana and Punjab were considered as “over exploited”, in respect of water use in 2016. These phenomena coupled with intensifying pumping, over use of groundwater, etc., would further deepen the water tablet to a tune of 50 m in most parts of Punjab state by 2023 (OECD/ICRIER, 2018).

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## Incidence of pests and diseases


The increasing temperature may lead to increased metabolic activity in insect pests. Crop losses will be aggravated in the regions where increasing temperature contributes to the population growth of insects and their metabolic rates (Deutsch *et al.,* 2018). In this context, the growth of the insect population will lead to increased herbivorous behaviour of insects which feed on crops, resulting in severe crop losses. The applied pesticides will be dissipated at rapid rates than under normal climatic conditions (Adults of *Nezara viridula* and *Halyomorpha halys* mortality rates may reduce by 15 for every 10°C increase in temperature, the migratory insects would last for long in the suitable regions. Precipitation has its own impact on the insect population. For instance, the onion thrips and cranberry insect pests are sensitive to high precipitation, these insects may be removed when exposed to high rainfall (Kambrekar *et al.,* 2015). Similarly, a few insects die in the drought-like conditions e.g. pea aphid. On the other hand, BHP populations show a mixed result of rainfall variations. For example, the incidence of BHP is more in the conditions of rainfall near about 400 ppm and is high when receives the rainfall more than 500 PPM (Kambrekar *et al.,* 2015). Although the use of pesticides, GMOs and agronomic practices have been advocated and adopted by farmers to mitigate the impacts of climate change, the efficiency of these control measure would be minimal amidst climate-induced pest and diseases. The elevated $CO_2$ could cause the *Spodoptera litura* to feed more on its host plant.

## Glaciers

Most of the glaciers fed river basins in the world are facing severe vulnerability due to change in climate systems. These melting ice and glaciers alter the hydrological systems, thereby affecting the quantity and quality of water resources (IPCCC, 2014). In India as well, most of the population are depended on glaciers fed river systems. Importantly, the rivers like Ganga, Indus, Brahmaputra etc., are glaciers based. The variations in climate might affect the river water flow and could deprive the water availability for both agriculture and human consumption.

## Recent observations on climate change and its impact on allied sectors

The livestock is equally suffering from climate change. Within the agriculturalsector, 7% of the livestock sector was affected by disasters including climate-induced disasters. The obvious effects of climate change/disasters on livestock are weakened body conditions and lowered animal productivity (Conforti *et al.,* 2017). The diseases/pests of livestock are migrating due to change in the climate. Bluetongue a disease which affects sheep and to some extent affect the goat and dee are spreading from tropics to mid-latitudes. The mortality rate of livestock is increasing due to a rise in temperature. In tropics countries, the mortality rate is even severe.The outbreak of Foot and Mouth Disease (FMD) in cattle was observed in Andhra Pradesh and Maharashtra to the tune of 52 and 84% due to temperature, humidity and rainfall; Mastitis increases in dairy animals during hot and humid weather, in turn, increases the flies and tick (National Intelligence Council, 2009).

Heat wave can reduce milk yield by 10-30% in first lactation and 5-20% in second and third lactation periods in cattle and buffaloes it also affects the growth, puberty and maturity of crossbreed of cows and buffaloes (NPCC 2004-07). The average weekly and monthly milk yield were reduced by 0.062 and 0.069 kg respectively for a% rise in relative humidity (Das, 2017). The physiological conditions of cattle such as rectal temperature and respiration rate were increased significantly per unit increase in air temperature, Relative Humidity and Temperature Humidity Index (THI). The fertility of dairy cows is reduced due to heat stress, besides, the heat stress reduces the estradiol secretion, thus increasing the interval of calving period. In the same way, heat stress would affect the growth of foetus due to the decreased blood supply to the uterus, thereby causing the placental insufficient to provide maternal nutrient (Das, 2017). In the summer the conception rate of cows may reduce up to 20-27% (Sejian *et al.,* 2016). On the other hand, increasing average minimum and maximum temperature are affecting the sperm concentration in bulls, thereby causing low ejaculation volume in summer than winter. The increasing temperature will further impede the availability of fodder and feed to the livestock, further, the formation of lignin content in the fodder and plant tissue due to high temperature could decrease the digestibility of livestock (Das, 2017). Annual enteric fermentation emission from India is about 10.27 TG. The methane emission is high among indigenous cattle breeds (48.5%) than crossbred or other livestock. Average methane emission for lactating animals was about 53.6 g CH4/kg milk (D.B.V. Ramana**)**. The milk yield of Holstein, Jersey and Brown Swiss was about 93, 97 and 98% at a temperature of 29$^{0}$C and relative humidity of 40%, whereas the yield of theses cows reduced to 69, 75 and 83%, when exposed to the relative humidity of 9% (Berman, 2005).The incidence of diseases are reported high among livestock, the hot weather climate causes clinical mastitis in dairy animals. The increase in cattle ticks such as *Boophilus microplus*, *Haemaphysalis bispinosa* is reported across the country due to hot humid weather conditions (Das, 2017).

Above 30$^{0}$C, the feed and energy intake of poultry birds decreases and causing a decline in production and the rising temperature could decrease the digestibility of nutrients in poultry, thereby affecting the nutrient supply to egg production, egg mass and shell quality of egg in layers and growth in broilers (Das, 2017). Fisheries have also impacted by the changing climate. The biological process and marine food systems are subject to severe stress due to change in the climate. The factors such as warming of Sea Surface Temperature, increased intensity of temperature, alternate current systems of Seawater etc. these factors coupled with overfishing and anthropogenic activities could impact the fish production systems across the globe (Lu, 2011). According to the ministry of agriculture, the milk production could decrease by 1.6 metric tones by 2020 and by 15 metric tons by 2050.

## Mitigation and adaptation towards climate smart agriculture

Climate smart practices and production technologies will help the farmers to mitigate the emission of GHG emission and adapt agriculture to the emerging agrarian issues of climate change. According to Sapkota *et al,* 2019, GHG emission from agriculture would be 489 $MtCO_2e$ by 2030 without any mitigation measures. However, the emission of GHG would be curtailed to 410 $MtCO_2e$ with the mitigation and Adaptation. I.e. technical mitigation has the potential of 78.67 $MtCO_2e$ per year, while, the restoration of degraded lands would enhance the mitigation potential up to 85.5 $MtCO_2e$ per year.

## Climate smart seeds/breeds

Climate smart seed/variety development encompasses a range of practices, which include conservation of plant genetic resources, the involvement of stakeholder in production, multiplication, processing, storage, distribution, marketing and dissemination of seeds/ improved varieties etc (Lipper *et al.,* 2014).

The key role of conserving the traditional seed varieties and using them to build a climate resilient cropping systems was adopted by the policymakers from across the landraces have become one of the climate adaptive strategies followed by the agricultural stakeholders in a changing climate. However, lack of availability of quality and improved seeds are the major challenge to the adoption. Most of the farmers in India have adopted the drought and pest tolerant as well as short duration crop varieties. About 80% and 70% of the farmers in North and south zones suffered from non-availability of improved seeds. For Example, KVK, Jalna has introduced a number of climate smart varieties in Kadegaon village of Jalna, Maharashtra to mitigate and adapt agriculture to climate change. The varieties such as BDN – 711 (Pigeon Pea-short duration rainfed variety), MAUS-71 (Soybean- non shattering and high yielding variety when cultivated on Broad Bed Furrow), Netravati -1415 (Wheat-Heat and low water requiring variety), Parbhani Moti (*Rabi* Sorghum-suitable for rainfed condition in *Rabi* season) and Digvijay (Bengal Gram-suitable for both rainfed and irrigated areas) recorded increased yield than conventional variety grown by the farmers in Kadegaon village of Jalna (Sonune and Mane, 2018).

In Heeranar village of Dantewada, KVK, Dantewada has demonstrated climate smart varieties such as Indira Barani Dhan-1 (short duration paddy varieties – suitable to reducing number of rainy days), Indira Ragi – 1 (Blast tolerance Ragi variety), Arka Rakshak (A tomato variety resistant to Bacterial and leaf curl), and TAU-2 pulses (Narayan *et al.,* 2018).

**Box-6: The flooding and the submergence of paddy – A case of Rayapuram in Tamil Nadu**

A sudden down pour is the major cause of climate change. Tiruvarur district of Tamil Nadu has frequently been affected by intensive downpour of North East Monsoon in the recent past, resulting in drowning of paddy for a period of 10-15 days. The paddy varieties such as ADT 38, ADT 46, Co 43, TRY 3 and CR 1009 grown by the farmers of Tiruvarur district, in particular Rayapuram village are susceptible to flooding. As a result of which, farmers lost about 75%of yield and total straw. Therefore, the changes in normal precipitation brought by climate change need to be offset by appropriate technology and extension advisory services related to flooding. The KrishiVigyan Kendra (KVK), Tiruvarur has created awareness among farmers about the flood tolerant varieties such as CR 1009 sub and Swarna sub 1 and has demonstrated the package of practices. Yet, KVK focuses mostly the National Innovation on Climate Resilient Villages (NICRA) adopted village like Rayapuram in the district. Thus, the appropriate climate funds, manpower, climate advisory models need to be strengthened to the diffusion of the flood tolerant varieties across the district. In the same way, the traders and consumers need to be informed about the salient feature of newly introduced varieties, which could facilitate the tradability of the new varieties and sustain the income of the farmers.

*-Ramesh et al., 2018*

## Breeds

For example, KVK, Dantewada is promoting Kadaknath poultry in backyard condition and to enable the farmers to earn additional income. It was reported that a unit of 50 birds could result in net income of Rs. 42,300, whereas, the net income from Broiler is only about Rs. 3,850. The rearing of Kadaknath has a B: C ratio of 15:67. On the other hand, B:C ratio for broiler rearing is not more than 2 (Narayan *et al,* 2018). The indigenous cattle breeds such as Sahiwal and Deoni have the high yielding potential under heat stress than Jersey and Red Sindhi Crosses (Das, 2017).

## Input smart

Input management has become a crucial part amid changing climate. The inputs right from fertiliser application to plant protection measures can have a positive effect in negating the impacts of climate change. The fertilisers such as slow release fertiliser, nitrificationinhibitors etc., could be chosen as the way of moderating the release of global warming gases by agriculture (Dickie *et al.,* 2014). Site specific nutrient management, soil test based fertiliser application, Deep Placement of Urea, Fertigation, Leaf colour chart for rice, slow release fertiliser etc. application of composting prepared from the farm wastes, compressed cakes of plant material and flower as manure, etc., Similarly, application of Mahua (*Madhuca indica*) cake, neem (*Azadirachta indica*) cake and Karanj (*Derris indica*) cake along with the Farm Yard Manure (FYM), application of Cetyl alcoholto reduce the evaporation from farm ponds,Application of KNO3 in cotton and soybean etc are good input management strategies to mitigate the climate change effect on crops.

Adoption of precision nutrient technologies coupled with the reduced Nitrogen consumption has the mitigation potential of 17.5 $MtCO_2e$ per year and could save about Rs. 65000 per $tCO_2e$ abated. However, the fullest adoption of precision application of fertiliserneeds changes in policy measures and efforts by farmers. In India, the subsidized Urea has become the cheapest source of N, thus, Urea accounts for 82% of the total consumption of N in India and mostly it is applied by broadcast method, rusting in the direct and indirect release of GHG emission (Sapkota *et al.,* 2019).

## Climate smart cropping management

Conservation tillage/no-tillage,crop rotation, contingency planning, changing the cropping calendar, use of trap crops, low water consuming crops, etc. are a vital part of cropping management. Crop diversification, Integrated Farming System, agro-forestry etc., have also been advocated as a part of climate mitigation options. Rice, fish and vegetable farming under Sunken and raised bed system has led to an increase in net income from farming. The average net income is calculated to be 1.2 lakh per ha. This farming system has a B: C ratio of 4.78. Similarly, the cropping systems such as Fruit crops + vegetables; fruit crops + pulses, tree crops (e.g. neem trees) + pulses etc., have

Rice+fish+vegetable farming system as a way to overcome the impacts of climate change been promoted to mitigate the impacts of climate change. The cultivation of climate smart crops such as Jowar, Maize and other minor millets could withstand the negative impacts of climate change as these crops are hardy, suited for semi-arid and tropics. For example, the rise in temperature has not altered the yield of Jowar in Andhra Pradesh from 1986 to 2010 (Padakandla, 2016). Changing the cropping pattern is often seen as one of the most desirable climate smart practices adopted by the farmers in India. This practice is most common among the farmers in the drylands tracts of India. In Karnataka, about 25 and 82% of the farmers in Gundlapalli and Saddapalli villages respectively of Bagepalli block (Chikballapur district) have changed their cropping pattern to mixed cropping to avoid climatic risks (Kattumuri *et al.,* 2015).

**Table 5. Climate smart cropping management**

| S. No. | Climate smart cropping management | Impact | Author |
|---|---|---|---|
| 1. | Maize (cv. Nilesh) intercropped with cowpea (cv. Hariyali Bush) under reduced tillage followed by mustard crop cultivation | This cropping system has a maize crop system productivity up to 200% and 230% net profit under this system in the rainfed areas (India) | Pradhan *et al,* 2018 |
| 2. | The shift of cropping pattern from food crops to vegetables and commercial cropping under increased adversity of climate change | 90 of the farmers in two villages of Nasik district (Maharashtra) have shifted the cropping pattern to grapes, sugarcane along with the production of vegetables and fruit orchards. The farmers in Guntur district of Andhra Pradesh reported that the paddy cropping area has reduced to 20% from 50% in the last 2 decades and was replaced by the chillies and wood plantations. On the other hand, horticultural crops have been promoted by the stakeholders of agriculture including the department of agriculture as a way to overcome the future possible climatic risks. In the state of Karnataka also, farmers have shifted from water-intensive crops (paddy) to low water-intensive crops. | Banerjee, 2015, Kattumuri *et al.,* 2015 |

| | | | |
|---|---|---|---|
| 3. | Crop diversification | Crop diversification has the ability to surpass the pests and disease outbreaks under climatic risks, particularly, it provides income stability. Likewise, crop diversification with agro-forestry was found to have higher organic soil stocks. Crop diversification towards horticultural crops has become more prominence in southern and western parts of India. In Saddapalli village (Chikaballapur district, Karnataka), 97% of farmers have diversified their cropping pattern from groundnut to drought-resistant horse gram and maize. | Kattumuri *et al.,* 2015 |
| 4. | Agro-forestry | Agro-forestry is gaining momentum owing to its capacity to generate additional income to the farmers. In Saddapalli and Gundlapalli villages in (Chikabalapur district, Karnataka), farmers have adopted at least three crops to provide sustainability to the farming. The tree species such as neem, Pongamia, coconut, mango, tamarind, custard apple, banana, drum stick, jack fruit, acacia, Syzygium, and pomegranate were planted by the farmers. Benbi et al found that wheat – rice – agro-forestry cropping system has the potential to sequestrate about 65-68% of the organic carbon stock in semi-arid regions of India. | Kattumuri *et al.,* 2015 and Benbi *et al.,* 2012 |

**Water/soil smart:** Around the world, different water-smart practices and technologies have been developed and disseminated to enhance the productivity of crops under climate stress. A range of adaptation options are available to improve the resilience of agriculture to water stress, which ison-farm water storage, watershed development, modernizing irrigation infrastructure,on-farm irrigation management (Drainage, alternate wet and dry etc.,), reallocation of water, protective irrigation etc.the use of micro irrigations is expected to enhance the irrigation water use efficiency by 90% (Lipper *et al.,* 2017). Zero tillage has been adopted as a soil and water conservation practice. Zero tillage has immense potential to increase the yield and reduce the cost of cultivation. Similarly, vegetative barriers, Conservation Bench Terrace, Peach Based Agri-horticultural Practises etc., have been followed in Uttarakhand and Himachal Pradesh states in India (Bhattacharyya *et al.,* 2016). The construction of small ponds called *Doba* water harvesting structures have become famous in Jharkhand state. The size of the doba structure may be of 3x2x1 m and has the capacity to withhold 4.5 $m^3$ of rainwater and the inner structure of Doba is lined with the black polythene sheet. Once the rainwater is received into the structure, and it is covered with the thatch, which is available locally. It was found that these structures were helpful in providing lifesaving irrigation to the establishment of the orchard (Dey and Sarkar, 2011).

In Central India (Madhya Pradesh), the water conserving practices like Broad Bed furrows (BBF) has resulted in 35% increase in yield in Soybeanand 21% increase in yield soybean, 30% in Maize and 16% in wheat. The conservation furrows have also had a greater impact on the yield (up to 15-20%) soybean, maize and groundnuts (Alfisol) in the state of Karnataka when compared to farmers practice (Bhattacharyya *et al.,* 2016). In Kyrdem village (Meghalaya), KVK, RiBhoi has demonstrated the importance of Jalkund for cultivating vegetables in lean season through NICRA. About 12 Jalkund (5x4x2 cu.m) with the capacity of storing 40, 000 litres of water was established in Kyrdem village. In this way, about 4.08 ha of lands were brought under vegetable cultivation by the farmers. In addition, the cropping intensity has increased 204% in Kyrdem village (Medhi *et al.,* 2018). In Tumkur, the demonstration of trench cum bunding in the NICRA project villages has decreased the soil erosion and increased the retention of soil moisture for a longer period of time. This intervention has increased the Finger Millet yield by 27% (Jasna *et al,* 2014).

**Box-7: Water smart climate adaptive technology – A case of Dry converted wet rice method in Telangana region, India**

Innovations in water saving crop production technologies have become an essential part of climate smart agriculture. Most of the Indian states started experiencing the deficit rainfall in past decade. The dry land tracts of India have become more prone to deficit or delayed monsoon than ever before. Telangana state in India has also suffered heavily from delayed or failure of monsoon. More often, in Khammam district of Telangana state, the farmers' practices of transplanting of rice has severely been affected in the recent past due to water shortage/non availability of water during transplanting as well as the transplanting of rice has further deprived the water resources. Therefore, Krishi Vigyan Kendra in Wyra, Khammam district has prompted **Dry converted wet rice** method as an alternative to transplanting. This method has proven to have leveraged the water requirement and reduced the labourer need. This method has hugely benefited the farmers as this method does not require nursery raising, pulling, transporting seedlings and transplanting since the rice seeds can directly be sown using seed dill on a well-levelled field.The assessment of this method shows that about 40-50% of water can be saved compared to the transplanted method. In addition, dry converted wet rice matures 7-10 days earlier as compared to transplanted crop. Presently in Khammam district, the area occupied under Dry Converted Wet Rice is more than 6000 ha. Further, the adoption of this method has led to a 30% (Rs 15,500 $ha^{-1}$) reduction in cost of cultivation. The Benefit: Cost ratio of Dry converted Wet Rice is about 2.49, whereas the B:C ratio in transplanted rice is only 1.78. Furthermore, the extension functionaries of KVK have persuading other rice growers to adopt the technology and to mitigate the dwindling water resources caused by climate change.

*-Hemantha Kumar et al., 2018*

In Heeranar village, Dantewada district (Chhatisgarh state), KVK, Dantewada has renovated two old stoops dams, five open wells. These renovations have led to an increased cropping intensity from 105% to 116%. Similarly, the productivity of rice and green gram was increased by 21.79 and 24.93% respectively owing to the longer availability of water for irrigation. Farmers have also started cultivating vegetables throughout the year under the *badi* System. On the other hand, creation farm ponds, percolation ponds have enabled the farmers to increase the area under rice and vegetable cultivation. It was recorded that the yield of rice and vegetables increased up to 21.33 and 35.69% respectively (Narayan *et al.,* 2018).

**Table 6. Mitigations and adaptations in soil and water conservation**

| S. No. | Water/soil smart | Impact | Author |
|---|---|---|---|
| 1. | Contour bunding | Contour bunds are capable of reducing the soil erosion, the areas with the contour bunds have reduced the soil loss by 0.3 t/ha from 18.92 t/ha. | Mishra and Tripathi, 2013 |
| 2. | Zero Tillage | Zero tillage has high water and fertiliser use efficiency when compared to conventional cultivation. It is estimated that farmers can reduce the input cost by 41% and increase the yield by 6% under zero tillage. In Indo Gangetic plains, the adoption of zero tillage in wheat-rice systems has provided the additional income of Rs. 6,951 per ha. When zero tillage combined with the adoption of improved seeds practiced in the wheat-rice system in Indo Gangetic plains, it has the potential to generate the net returns up to Rs. 15, 303 per ha. Besides, adoption of ZT in rice, wheat, cotton and sugarcane would abate the GHG emission of 15 Mt$CO_2$e per year and save the cost of Rs. 42000 per tonnes of $CO_2$e saved. | Khatri-Chhetri *et al.,* 2016 and Sapkota *et al.,* 2019 |
| 3. | Watershed management | Watershed development often adopted as a way to address the problems of rainfed areas in the country. According to Bhattacharyya *et al,* the benefits of watershed programmes include augmented income, rural employment generation (151 person days ha´1 ), increased crop yields and cropping intensity (36%), decreased runoff (45%) and soil loss (1.1 t¨ ha-1 ¨ year-1), augmented ground-water and decreased poverty). Besides, the effectiveness of watershed development is dependent on the rainfall pattern. | Bhattacharyya, *et al.,* 2016) |
| 4. | Conservation furrows in Soybean | The demonstration of conservation furrows (Soybean) in Babhulgaon and Ujalamba NICRA villages, Marathwada (Maharashtra) helped the farmers to increase the yield, net returns and RWUE on average of 1502/ha, 22571/ ha and 3.19Kg/ha/mm respectively in five years (2011 – 2015) under delayed on a set of monsoon. Besides, adoption of conservation furrows in intercropping of Soybean and red gram has additional yield and RWUE with 1650 kg/ha and 3.83 Kg/ha/mm. the average net return form the intercrop is about Rs. 31456/ha | **B.V. Asewar** All India Coordinated Research Project for Dryland Agriculture VNMKV, Parbhani, (M.S.) |

| | | | |
|---|---|---|---|
| 5. | Maize-based production systems as conservation agriculture production systems | In the upland areas of Odisha, the grain yield of mustard and horse gram has increased to 25 and 37% respectively, when grown after Maize intercropped with cowpea. Moreover, the residue retention of mustard in the field had a beneficial impacton productivity and net benefits. | Pradhan *et al.,* 2016 |
| 6. | Mulching | Mulching plays a vital role in the conservation of moisture and controlling weeds and further spread. In Kyrdem village (Meghalaya), KVK, RiBhoi has helped the farmers to adopt mulching in ginger and turmeric on raised beds across the slope. About 40 farmers' field was demonstrated with the importance of mulching. It was found that the mulching has increased the income by 2.56 times in Ginger and 2.67 times in Turmeric. Besides, there was 30-35% and 60-65% reduction in weed growth and soil erosion respectively. In terms of yield, after the mulching/ intervention, the yield of Ginger (Var. Nadia) has increased to 250 q/ha from 85 q/ha. Similarly, the yield of Turmeric has increased to (Var. MT1) to 310 q/ha from 225 q/ha. The BCR ratio of Ginger has increased to 2.70 from 1.70 after mulching intervention, while, the BCR ratio of Turmeric has increased to 2.81 from 1.74. | Medhi *et al.,* 2018 |
| 7. | Laser Land Levelling (LLL) | The adoption of Laster Land Levelling by the farmers in Indo Genetic plains has made a significant impact on high net return. The use of LLL in Wheat – Rice system has increased the net income to Rs. 8,1119per ha per year. Moreover, the adoption of LLL in rice-wheat cropping system would abate the GHG emission by 4 Mt$CO_2$e per year and save about Rs. 1940 per year for every tonne of $CO_2$e saved. | Sapkota *et al.,* 2019 |
| 8. | Micro-irrigation | Water management practices such as sprinkler, drip irrigation and fertigation together may abate the GHG emission up to 5.5 Mt$CO_2$e per year. The key benefits of the adoption of micro irrigation include water use efficiency (50-90%), expansion cropped area, the introduction of new crops, electricity saving up to 30.5% due to the small power units etc. | OECD/ ICRIER, 2018 and sapkota *et al.,* 2019 |

| | | | |
|---|---|---|---|
| 9. | Happy Seeder | The application of happy seeder in Punjab regions has reduced the air pollution because the happy seeder allows the farmer to sow the wheat seeds without burning the stubbles of paddy. | Groot *et al.*, 2019 |
| 10. | Organic farming | Organic farming lowers the $N_2O$, and $CO_2$ emission and increases the Soil Carbon Content. Enhances the biodiversity and soil microorganism, minimizes the indiscriminate use of pesticides, enhances the fertility of the soil, and promotes the use of soil, water and air in a healthier way. | Sartaj *et al.*, 2013 |

## Policy and Program smart

Polices play a crucial role in minimising the impacts of climate change. Climate smart policies have become a central state with the convention on the United Nations Framework Convention on Climate Change (UNFCCC). UNFCCC was come into being in 1992, which aimed at reducing the risks of Climate change and to adapt to the future uncertainties of climate change. Kyoto Protocol-11$^{th}$ December 1997,Kyoto, Japan- legal binding established for industrialized Nations to reduce the emission of six GHG's($CO_{2,}$ $CH_{4,}$ $NO_2$, Sulphur hexafluoride, hydro fluorocarbons and Per fluorocarbons) 5.2 per cent reduction during 2008-2012 from1990 emissions. An arrangement under the Kyoto Protocol allowing industrialized countries with a GHG's reduction commitment to invest in ventures that reduce emissions in developing countries as an alternative to more expensive emission reduction in their own countries-Base year 1990. The long term goal of the Paris agreement is to keep the temperature rise well below $2^0$C from the pre-industrial level.

In most of the states, the major policy interventions like The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA, 2005) undertake the climate resilient activities such as the creation of mini watershed areas, water conservation, excavation/renovation of reservoirs/ponds, other rainwater harvesting structures, tree plantation and maintenance, etc. Thus, the scheme like this could enhance the resilience of agriculture and allied sectors during severe droughts and other climatic risks (Udmale *et al.*), 2014. The farmers in Saddapalli and Gundlaplli villages, Chikabalapur district in Karnataka state have joined in MGNREGA after the crop loss resulted from the vagaries climatic conditions. It is reported that 82 of the households in these villages have gained employment opportunities from MGNREGA. Most of them were employed during the winter season. Thus, the scheme has provided a substantial income to the farmers in these villages, which compensated the income loss from agriculture due to climate change (kattumuri *et al,* 2015).

Most often, policies of climate change aimed at mitigation and adaptation mechanisms. Polices are complementary to the adaptation processes, which include, Research and

Development, Capacity Building, Risk Aversion, Infrastructure and Funding Mechanism (Ignaciuk, 2015). A number of insurance policies are devised and implemented to avert the risks posed by climate change. The government of Maharashtra signed the Maharashtra Project for Climate Resilient Agriculture agreement with the World Bank with the help of the government of India. An amount of 420 million US dollor will be given by the International Bank for Reconstruction and Development (IBRD) to implement the project, the project will benefit about 25 million small and marginal farmers in the areas of Marathwada and Vidarbha regions of Maharashtra. Also, it encompasses serious activities, which include on the farm and off-farm watershed development programmes, dissemination of climate resilient technologies such as micro-irrigation systems, expansion of surface water storage system, facilitation of aquifer recharge, popularisation of climate resilient seed varieties (e.g. drought, salt, heat-tolerant varieties). Likewise, the emphasis is given to enhance the capacity of farmers'organisation such as local farming institutions,

Farmers Producers Organisations, agri enterprises, thereby ensuring the timely agro advisories and extension services to overcome the climate risks (PIB, 2019).

## Extension/knowledge smart

The first step towards, adaptation measure to climate change is bringing desirable change among farmers. A number of factors influence the behaviour of farmers, which include externals and internals. Externals such as subsidies, climate finance, incentives, extent of participation, linkages with the stakeholders relationship with fellow farmers, friends, neighbours and internals such as education, knowledge, awareness, attitude, education, farm size, family income, family labour on agriculture, etc. for which, extension advisory services play a major role

**Box-8: National Mission on sustainable agriculture - India's National Action Plan on Climate change**

India's National Action Plan on Climate change was implemented in 2008 with the eight sub schemes *viz.*, (i) National Solar Mission, (ii) National Mission for Enhanced Energy Efficiency, (iii), National Mission for Sustainable Habitat, (iv) National Water Mission (v) National Mission for Strategic Knowledge on Climate Change (vi) National Mission for Sustainable Agriculture, (vi) National Mission for Green India and (viii) National Mission for Sustaining the Himalayan Ecosystem.

The National Mission of Sustainable Agriculture (NMSA) was launched in 2013 with the focus on soil and water conservation, water use efficiency, soil health management and rain-fed area development. A number of programmes, climate smart initiatives, schemes have been integrated and mainstreamed into NMSA, which include System of Rice Intensification (SRI), the National Initiative on Climate Resilient Agriculture, Parampragat Krishi Vikas Yojana (PKVY), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), National Food Security Act, 2013, Pradhan Mantri Fasal Bima Yojna (PMFBY) et., these sub components of NMSA encompass various climate related activities. Yet, the policy gives more emphasis to Rainfed Area Development (RAD), which covered about 12 thousand ha of Integrated farming system, about 28 thousand ha of livestock based farming system, about 46 thousand of water harvesting and management structure (tanks, community water harvesting ponds and so on), etc during 2018-19. Similarly, 1,751 trainings and 456 demonstrations were done under RAD of NMSA.

Climate smart technologies have become knowledge-intensive, hence, these knowledge-intensive technologies pose considerable challenges to farmers regarding adoption and continued adoption In the absence of relevant extension and advisory services, the adoption of climate smart technologies would be trivial (Hellin *et al.,* 2014). In order to respond to climate change, a range of extension mechanism to be kept in mind. These extension modalities include indigenous knowledge, farmers collectives, climate training, Plant Health rallies, Climate Famers Field School, Participatory crop planning, the establishment of plant clinics, climate manager, monsoon manager, climate awareness campaigns, climate finance, incentives at farmers level (Rupan *et al,* 2018). Access to climate information and awareness about climate-associated risks in agriculture are an essential part of mitigation and adaptation. A number of initiatives have been taken by agricultural stakeholders across the globe to address the risks and impacts of climate change. Access to climate information has become a crucial part of farm level decision making regarding adaptation. Capacity building programme has greatly impacted the adaptation practices of farmers in the Nagarjuna Sagar Project Command Areas. The practices include Alternate Wetting and Drying (AWD) in rice, Modified System of Rice Intensification (MSRI) and Direct Seeding of Rice (DSR). The capacity building helped the farmers to increase the rice yield. Agromet Advisories of CRIDA, are the bulletins prepared and disseminated to the farmers, the bulleting includes weather events for the past, present and future (at least 5 days ahead),stage wise information of crops and related farm activities or production practices to be taken up to mitigate the impacts of future weather changes. For example, the number of farmers in Bijapur district was benefited from the advisory services and by adopting right practices advocated through Agromet bulletin (**V.U.M.Rao, CRIDA**). Studies found that farmers with better access to the agrometeorological services have increased the farm income.

**Table 7. A few examples of farmers who have benefited from Agromet Advisories**

| S. No. | Farmer & Village | Forecast provided | Forecast used for | Benefits/savings |
|---|---|---|---|---|
| 1. | Mr Shivaji Dege, Aheri | No rainfall in next 3-4 days | Spraying was deferred | Saved one spray costing Rs.4000/- per acre. |
| 2. | Devanayak, Honawad | Rainfall expected within 24 hr | Immediate spraying for disease | Saved losses to the extent of Rs, 60,000/- per acre. Non Adaptors incurred loss. |
| 3. | Shivalingappa Marebaddi, Mugalkhod | Chances of rainfall after two days | Immediate Harvest of soybean | Got Rs. 1900/- per quintal against 1400/- of others who harvested after a rainfall event |

*Source: V.U.M. Rao, CRIDA*

Various ICT supported climate extension services have been implemented by a variety of public and private institutes. The establishment of ICT hubs and Village Access Centre by ICRISAT at Addakal block has been a successful ICT initiative amid climate change. ICRISAT with its core partner Adarsha Mahila Samaikya (AMS), a federation of women Self-Help Groups (SHGs) in the block identifies a group of Village Network Assistant (VNA), in order to disseminate the climate information and adaptive strategies based on the farmers' quarries. In India, block-level weather forecasts are provided to farmers in 25 NICRA districts. KVKs/ Programme Coordinators are disseminating the capsule of weather forecasts along with crop advisory to prepare and to respond to the weather forewarning. The multiple communication channels *viz.*, mobile text, SMS, Voice messages, display at commonplace, personal contact etc., are used to disseminate the information. Notably, Field Information Facilitator (FIF) employed at micro/village level collects the real time field situations of crops, growth stages, pest and disease incidence etc., and send to KVKs. KVKs prepares crop advisories based on the field information collected from FIF and weather situation from IMD and crop advisories are communicated to the farmers by FIF. Micro-Level Agromet Advisory Services (MAAA) have helped the farmers to respond to climate change in advance, thereby avoiding the risks posed by climate change (Vijaya Kumar *et al.,* 2017). Real Time Contingency Planning has also gained momentum in India. RTCP helps in overcoming agrarian issues such as the delayed on set of monsoon, seasonal droughts and floods (Rao *et al,* 2016). The impacts of Real Time Contingency Planning have been conspicuous throughout the country.

**Table 8. Change in weather and advisory services; their impacts**

| S. No. | District/state | Crop | Weather aberrations | Contingency measure | Yield (Kg/ha) With RTCP | Yield (Kg/ha) Without RTCP | B:C Ratio with RTCP |
|---|---|---|---|---|---|---|---|
| 1. | Hoshiarpur (Punjab) | Pearl millet | Delayed onset of monsoon | Drought tolerant variety – FBC-16 | 4300 | 3400 | 2.89 |
| 2. | Lakhimpur (Assam) | Potato (Kufripokhraj) | Early season drought in rainfed areas | Supplementary irrigation of 9.4 cm during stolon formation and tuber growth stage | 26750 | 12100 | Up to 3.87 |
| 3. | Indore (Madhya Pradesh) | Soybean | Mid-season drought in rainfed areas | Foliar spray with Mo@0.1% in 2 sprays | 412 | 399 | 2.03 |

*Rao et al, 2016*

## Energy Smart

Manure management is an important source of GHG emission in India. However, the establishment of biogas plants may mitigate GHG. In order to increase the establishment of biogas plants, the appropriate incentives and funds are essential. Similarly, cultivation of bioenergy plants needs to be promoted in the degraded lands, which not only help in carbon sink but also meet the bioenergy need of the burgeoning population. Moreover, biochar and bio gas production, solar pump sets,conversion of waste lands into greenery and energy smart activities can be promoted.

## Institutional smart

A number of institutional arrangements such as, farmers groups, Panchayats institutes, commodity groups, value addition groups,Custom Hiring Management Committee, seed banks, fodder banks, farmers collectives for inputs management and marketing, etc play a crucial role in mitigation and adaptation. Managerial and institutional innovations are more likely to play an important role in dealing with the impacts of climate change. Village Climate Risk Management Committee (VCRMC) has been established under NICRA across the country. VCRMC consists of 12-20 members; representing all sections of the community with at least 2-3 women members, elected/ selected President, Secretary and Treasurer, VCRMC has to open a

**Box -9: Custom Hiring centre**

Use of machinery has become more among the farmers. In Dantewada, KVK under NICRA project has established CHC, which has the farm machinery such as power tiller, ridge maker, treasure, reaper, seed cum ferti drill, paddy transplanter, land leveller, conoweeder sprayer. It was found that farmers have increasing using the machinery. The use of power tiller, seed drill, thresher and paddy transplanter could result in savings of 70-75% of labour cost. Similarly, 40-45% of the labour cost can be saved wit the use of conoweeder and wheel hoe. The rent fee charged from farmers is deposited in the bank account of VCRMC (Narayan *et al,* 2018).

bank account operated by any two (President, Secretary and Treasurer), each transaction of money withdrawal to be accompanied by a resolution, sources of revenue, proceeds of CHC, contribution of community towards interventions. The water use institutions or associations such as Participatory Irrigation Management (PIM) and Water Use Associations (WUAs) are instrumental in augmenting the efficiency of water usage (Dev, 2018). There are about 56, 539 WUAs managing 13.16 m.ha of irrigated lands (NITI Aayog, 2015).

## Allied sectors smart

The climate smart practices of livestock should provide an ambient environment to improve the production of milk, meat and wool. A number of allied smart practices have been adopted by the farmers across the country, which include shades for livestock (improves productivity and milk yield); grazing at night hours for 2-3 hours; increasing the concentration of minerals in feed (1.5-16% of DM of potassium, 0.5-0.6% DM of Sodium) have the potential to improve milk yield under heat stress conditions, 6g/cow/day of niacin would increase the milk yield; 150-200g/cow/day Sodium bicarbonate helps in buffering the rumen during hot conditions); the technology like Embryo Transfer Technology (ETT) enhances the reproduction of bovine under heat stress; Integration of allied sectors with farming can be an option to mitigate the impacts of climate change. There exists a number of ways agriculture smart through the allied sector, which includes use of community lands for fodder production during droughts and flood, improved fodder and feed storage methods, feed supplements, use of micro nutrients, preventive vaccination, improved shelters, etc. (Kumar *et al.,* 2018). Increasing the green fodder and concentrate feeds for lactating cattle and buffalo, the feed additives such as monensin and molasses urea products to cattle and buffalo and improved manure management may mitigate the options to mitigate the impacts of climate change (Sapkota *et al.,* 2019). As livestock is the largest contributor to the GHG emission in the agricultural sectors, several mitigating measures have been advocated by the stakeholders to abate the emission of methane and nitrous oxide. The options such as improving the rumen fermentation efficiency, increasing green fodder dietary consumption (increased green fodder feed may reduce methane production by 5.7%), increasing the concentrate feed (The increased concentrate feed would reduce methane production by 15-32%), ensiled feed from forage reduces the methane production due to maximum digestibility; increasing the intake of feed additives (ionophores, antibiotics, halogenated compounds like condensed tannins, saponins or essential oils, propionate precursors (Fumarate and malate), culling of unproductive animals, increasing the use of IVRI rumen manipulation technique to reduce the emission of methane etc. likewise, manure management is a cause for the emission of GHG. In Maharashtra, several cattle camps have been organised by the government in the drought-prone areas to ensure the fodder and feed the demand of the livestock and the families dependent on the livestock (Udmale *et al.,* 2014).

## Summary

The impacts of climate change have been visible in the field of agriculture and caused a huge crop loss and income loss to the farmers as learnt in the chapter. Further, climate change in the agricultural and allied sectors has caused a severe socio-economic strain to the farmers as well as to the economy of the country. However, it is been observed that various adaptation measures promoted by research and extension system have reduced the adverse effects of climate change on crop and livestock production and productivity. It is also understandable from the chapter that numerous climate smart practices are followed by farmers have different success rate and adoption rates. On the whole, the adverse impacts of climate change can be minimised by the aggressive extension system by professionally identifying the anticipated and the existing vulnerability in the local areas (It will vary with the locations), screen the available technologies in the research organisations and universities, demonstrate them in the farmers field, which are suitable to the identified vulnerability and organise the farmers as collectives, provide real time weather and market related advisory services etc. would enable the farmers to prepare them to the emerging challenges of climate change.

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# 43. Innovations in Extension Delivery in India


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Agriculture has been a way of life in India and continues to be the single most important livelihood of the masses. The share of agriculture in real GDP has fallen given its lower growth rate relative to industry and services. However, what is of concern is that growth in the agricultural sector has quite often fallen short of the Plan targets. During the period 1960-61 to 2010-11, food grains production grew at a compounded annual growth rate (CAGR) of around 2 per cent. The Ninth and Tenth Five Year Plans witnessed agricultural sectoral growth rate of 2.44 per cent and 2.30 per cent respectively compared to 4.72 per cent during Eighth Five Year Plan. During the XI Five Year plan, agriculture growth is estimated at 3.28 per cent against a target of 4 per cent. The Approach Paper to the Twelfth Five Year Plan emphasises the need to "redouble our efforts to ensure that 4.0 per cent average growth" is achieved during the Plan if not more. Without incremental productivity gains and technology diffusion across regions, achieving this higher growth may not be feasible and has implications for the macroeconomic stability given the rising demand of the 1.2 billion people for food. Achieving minimum agricultural growth is a pre-requisite for inclusive growth, reduction of poverty levels, development of the rural economy and enhancing of farm incomes (Economic Survey 2011-12, *http://indiabudget.nic.in/survey.asp)*

Challenges of climate-change related phenomena, depleting natural resources, scarcity for agricultural labour, rising costs of inputs, uncertain market prices and declining interest amongst farmers in the farming profession are further compounding the challenges more intensely than ever before. Rural youth, particularly the young men, are losing faith in farming as a livelihood option and showing more interest towards non-farming activities in urban areas. Farming in India is thus getting transformed into an ageing and feminised profession.

Agriculture being a State subject, it is the responsibility of the State Governments to ensure growth and development of the sector in their respective States. At the national level, Department of Agriculture and Cooperation (DAC) under the Ministry of Agriculture (MoA) oversees the overall development of agriculture sector in the country. It is responsible for formulation and implementation of national policies and programmes aimed at achieving rapid agricultural growth through optimum utilization of land, water, soil, plant and human resources of the country. Several Extension Programmes have been launched and implemented that have contributed for green, white, blue and yellow revolutions.

## National Policies and Extension Programmes

### National Agricultural Policy (NAP), 2000

Issues that were highlighted under Transfer of Technology in NAP 2000 have been summarised as below:

- Strengthen research- extension linkages to improve quality and effectiveness of research and extension system.
- Broad-base and revitalize the extension system. Introduce innovative and decentralized institutional changes to make the extension system farmer-responsible and farmer-accountable.
- Encourage Krishi Vigyan Kendras (KVKs), Non-Governmental Organizations (NGOs), Farmers Organizations, Cooperatives, corporate sector and para-technicians for organizing demand driven agricultural extension.
- Develop human resources through capacity building and skill upgradation of all extension functionaries.
- Move towards a regime of financial sustainability of extension services through a more realistic cost recovery of extension services and inputs, while simultaneously safeguarding the interests of the poor and the vulnerable groups.
- Mainstream gender concerns in agriculture through appropriate structural, functional and institutional measures that will empower women, build their capabilities and improve their access to inputs, technology and other farming resources.

### National Policy for Farmers (NPF), 2007

The National policy for Farmers proposed following action points for extension:

- The gap between scientific know-how and field level do-how would be overcome speedily to enhance farm productivity and profitability. *Krishi Vigyan Kendras* (KVKs) would take up training and lab-to-land demonstrations to provide skilled jobs in villages.
- State governments would be supported for strengthening the extension machinery through retraining and retooling of existing extension personnel and for promoting farmer to farmer learning by setting up farm schools in the fields of outstanding / progressive farmers. The farm schools with linkages to KVKs can speed up the process of technological upgradation of crop and animal husbandry, fisheries and agro-forestry.
- Bring farmers, processors, retailers and other stakeholders together to support modern agricultural practices. Convergence of extension efforts especially at the district level and below would be ensured.

- Common Service Centres (CSCs) of the Department of Information Technology, Government of India and those set up by the state governments and private initiative programmes will be evolved for inclusive and broad-based development.
- Empowering farmers with the right information at the right time and place is essential for improving the efficiency and viability of small and marginal holdings. Mass media, particularly the radio, television and local language newspapers, will be used to play an important role in this regard.

## Extension Programmes Through Five-Year Plans:

Five Year Plans had many implications particularly for initiating new government programmes and policies. The **Sixth Five Year Plan** period coincided with the introduction of T&V system. In the **Seventh Five Year Plan**, the World Bank assisted National Agricultural Extension Projects (NAEP) I to III were in operation in which thrust was given to broad-base the extension activity by moving away from the narrow individual crop orientation to farming systems approach.

The main thrust areas of the **Eighth Five Year Plan** included, *inter alia* (a) accelerated growth in areas which had relatively low growth; (b) development of rainfed areas using adoption of dryland farming system approach; (c) diversification into animal husbandry, dairy, horticulture, sericulture, fisheries, and agro forestry for small and marginal farmers; and (d) involvement of NGOs in integrated development of rainfed areas through watershed development programmes. In the middle of the Plan period (1994-95), however, two new schemes were introduced to encourage involvement of people in transfer of technology. These were (a) Extension through Voluntary organisations; and (b) Women in Agriculture. The six schemes of ICAR implemented through agricultural extension were integrated in this Plan and put under the canopy of Krishi Vigyan Kendra (KVK).

The agricultural development strategy for the **Ninth Five Year Plan** basically addressed the issue of food security. A regionally differentiated strategy based on agro-climatic zones to take into account agronomic, climatic, and environmental conditions to realise the full potential of every region was emphasised. The Plan noted that (a) lack of adequate manpower; (b) the declining importance of T&V system; and (c) lack of professionalism affected the extension services.

**The Tenth Five Year Plan** emphasised on extension reforms to make extension services demand driven, for which following specific agenda were set-in:

- Encourage the role of the non-government sector in agriculture extension and an innovative approach in the field of television/ radio broadcast.
- Extension workers to be reoriented and retrained to adapt themselves to developments in communication technology and make full use of emerging opportunities.

- Communication networking will be encouraged to have backward linkages with the private sector. Private sector would also be encouraged to provide extension services.
- Strengthen the scheme 'establishment of agri-clinics / agri-business centres / ventures by the agricultural graduates'.
- Strengthen the interaction of KVKs activities with the State / District extension machinery.
- Revitalise the extension system and broad base it through KVKs, NGOs, farmers' organisations, cooperatives, the corporate sector and agri-clinics / agri-business centres.

**The Eleventh Five Year Plan** reiterated the key role to be played by Public extension system in educating farmers and helping them to take right decisions. Infrastructure to support capacity building of farmers below district level was emphasised by up-scaling ATMA to all development districts. Efforts were made to incorporate provisions to enhance the acceptability of the scheme by States and effective operationalization of the scheme in true spirit.

- The document clearly spelt out the need for avoiding duplication of efforts with multiplicity of agents attending extension work without convergence. Co-ordinated attempt to synergize and converge these efforts at the district level and below were targeted to improve the performance of various stakeholders.
- It also specified the need for the research and extension agenda of the district to be set by multi-disciplinary team involving scientists, extension workers, farmers, and other stakeholders by giving due regard for research–farmer–extension–market linkages.
- Public–private partnership (PPP) in extension has to be promoted for convergence and sharing of resources.
- The document particularly highlighted following challenges that the Extension System should address:
    - How to bridge the yield gap between demonstration plot and farmers' fields? While technologies more adaptable to wider regional variations are required, effective extension remains vital for realization of demonstration plot yields at farmers' field on a large scale.
    - How to deliver knowledge to all farmers, and especially how to involve and motivate the resource-poor farmers with a holding size below 1 hectare to take command of their situation and reduce the innovation adoption period?
    - How to organize the farmers around the commodity for getting them the benefits both mutually within the community and in interaction with external agencies supporting the development process?

- o How to develop farmer's organizations and federate them at Block/District/State level and linking their economic activities with the market to attain the power of scale economies and collective bargaining to the advantage of farmers?

First year of the **Twelfth Five Year Plan** (2012-2017) has just started and it is turning out to be a watershed plan for Extension. The Finance Minister of Union Government of India, in his budget speech for 2012-13 on 16.03.2012, has announced a Mission on Agricultural Extension and Technology. The Finance Minister announced that agriculture will continue to be a priority for the Government. The total plan outlay for the Department of Agriculture and Cooperation was increased by 18 per cent from Rs.17123 crore in 2011-12 to Rs.20208 crore in 2012-13. The Finance Minister also announced the intention of the Government to merge the ongoing programmes into a set of missions to address the needs of agricultural development in the Twelfth Five Year Plan. These Missions are:

i. N*ational Food Security Mission* which aims to bridge the yield gap in respect of paddy, wheat, pulses, millet and fodder. The ongoing Integrated Development of Pulses Villages, Promotion of Nutri-cereals and Accelerated Fodder Development Programme would now become a part of this Mission;

ii. *National Mission on Sustainable Agriculture* including Micro Irrigation is being taken up as a part of the National Action Plan on Climate Change. The Rainfed Area Development Programme will be merged with this;

iii. *National Mission on Oilseeds and Oil Palm* aims to increase production and productivity of oil seeds and oil palm;

iv. ***National Mission on Agricultural Extension*** *and Technology* focuses on adoption of appropriate technologies by farmers for improving productivity and efficiency in farm operations; and

v. *National Horticulture Mission* aims at horticulture diversification. This will also include the initiative on saffron.

The Department of Agriculture and Cooperation is working on the Mission Documents to get the approval of the GOI for their implementation in XII plan.

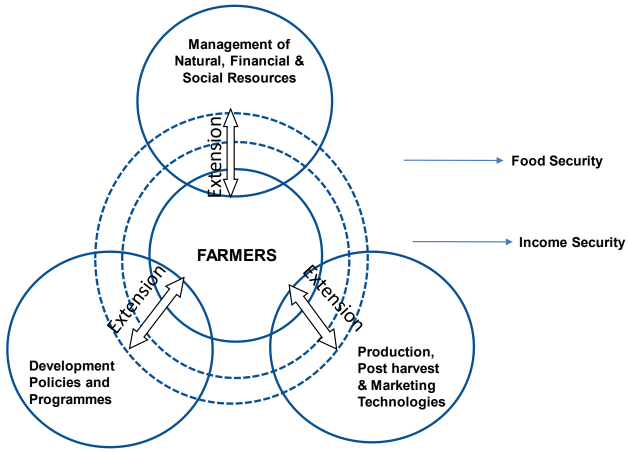
## Role of Extension in the Changing Agricultural Scenario

National Commission on Agriculture (1976) refers to extension as an informal out-of-school education and services for the members of the farm family and others directly or indirectly engaged in farm production, to enable them to adopt improved practices in crop, livestock and fisheries production. It also aims at changing the outlook of the farmer to the point where he will be receptive to and on his own initiative, continuously seek means of improving his farm occupation, home and family life in totality. The Commission regarded extension as an investment in modernising the outlook of the farming community including that of the women farmers (Sanghi *et. al.* 2004). Extension has been recently defined as a professional communication intervention deployed by an institution to induce change in voluntary behaviours with a presumed public or collective utility (Roling, 1988). Dwarakinath (2009) summed up that extension services relate relevant external knowledge to the farmers' problems, needs and opportunities through a system of communication associated with non-formal, adult education.

Extension has been the cornerstone of the agricultural development in the county. The green revolution has been possible because extension system succeeded in disseminating appropriate technologies and right cropping practices to large, widely scattered and heterogeneous farming community. While the number of farm holdings has been constantly increasing due to fragmentation, farmers' needs in terms of information and technology support have also been on a constant rise. More importantly, the resources *viz.*, natural (land, water, air, flora& fauna etc.,) economical (availability of inputs including credit & labour, market prices, input costs etc.) and social (community, groups & family) are not favourably disposed towards the situations and circumstances under which farmers decide and practice farming operations. Farmers need advanced and appropriate technologies and policies/programmes to accept and adopt such technologies.

The critical role that extension plays or required to play is to expand the horizon of farmers, in terms of their knowledge, skills and attitudes about the management of natural, economic & social resources; about the government policies and programmes; and about the available basket of technologies (production, post-harvest and marketing) so that farmers make informed decisions to benefit from all these and in turn benefit the society at large (Fig 1). Changes do not happen unless framers accept policies & programmes, and adopt technologies on a continuous basis. Hence farmer is central to the entire change process. Extension facilitates farmers to benefit from the development policies and production technologies. Helping the farmers to overcome constraints in mobilizing social and financial resources and the depleting natural resources are fundamental to the extension agenda.

**Fig1. Extension's Role in the Changing Agricultural Scenario**




*Extension widens farmers' awareness about technologies, development policies & programs and empower farmers to manage resources, individually and collectively, by making use of technologies & programs*

Source: Author

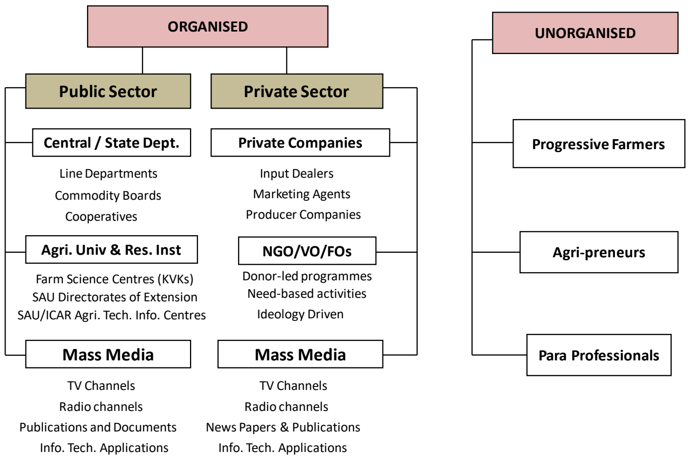
The changing farmers' priorities from production to income have shifted the extension emphasis to help farmers to organize themselves and to link them to markets. According to Sulaiman and Hall (2004), other important roles that extension needs to play are (i) building coalitions of different stakeholders; (ii) promoting platforms for information sharing; (iii) experimenting with and learning new approaches; and (iv) acting as a 'bridging organization' that provides access to knowledge, skills and services from a wide range of organizations including research institutions.

## Plurality of Extension Delivery Mechanisms in India

The extension services in India are highly pluralised. Numerous agencies are now providing extension service in varied nature through different approaches. Broadly, extension service providers in India could be categorized into three systems, *viz.*, public extension system, private extension system and individuals-based extension system. While the first two systems are more or less organized in nature, the latter system is more unorganized.

Agriculture is a state subject and each state has its own programmes and policies to support extension services to its farming community. The Central Government Ministries (Agriculture, Commerce, IT, Rural Development etc.) have their own programmes and schemes to support the states in strengthening their farmer oriented services. The Agricultural Research and Education has been the primary domain of ICAR Institutes and Agricultural Universities (SAUs, CAU, DU). These research and educational institutions also have their own extension initiatives to reach farmers.

**Fig 2.Extension Service Providers in India**




Source: Author

The private extension system involves a heterogeneous group of extension providers. The extension network of private companies comprising of its own agents and the input dealers is considerably strong. The mass media employed by the private extension systems like private TV channels, FM radio, community radio and print media are also reaching a sizeable proportion of farmers. Emergence of information technology and its application to extension have started making inroads in advisory services. Though the information providers are few in number, extension services offered through information technology is attracting the imagination of many.

The Department of Agriculture and Cooperation (DAC), Government of India has been implementing several centrally sponsored (implemented through state governments with partial budgetary contributions) and central sector (implemented through central/state/private institutions with 100% financial support) schemes. The DAC, through its Directorate of Extension has been implementing following programmes:

- Centrally Sponsored Scheme “Support to State Extension Programmes for Extension Reforms” is being implemented in all the states by way of new institutional arrangements for technology dissemination, wherein Agricultural Technology Management Agency (ATMAs) have been established at the District level.
- Central Sector Scheme Establishment of Agri-Clinics and Agri-Business Centres (ACABC) supports establishment of private agri-ventures which in turn supplement state agricultural extension services.
- The scheme of Mass Media Support to Agricultural Extension is being implemented to provide information to farmers on matters related to agriculture production through

a network of Television and FM radio channels throughout the country, besides establishment of Community Radio Stations.

- In order to help farmers in tackling multifarious problems relating to their farm activities, 'Kisan Call Centres' have been established to reach out to all category of farmers at free of cost through national toll-free number, in their own language and at a time convenient to them.
- In order to provide continuous, need-based and horizon-expending avenues for human resource development of extension officials, National Institute of Agricultural Extension Management (MANAGE), Extension Educational Institutes (EEIs) and State Agricultural Management & Extension Training Institute (SAMETIs) have been organizing training programme at different levels to meet the HRD needs of different category of extension personnel.
- Agricultural Exhibitions, Regional Fairs, Newspaper Ad campaigns etc. further supplement the extension initiatives of DAC.

## Support to State Extension Programmes for Extension Reforms (ATMA Scheme)

Centrally Sponsored Scheme **"Support to State Extension Programmes for Extension Reforms"** was launched in the year 2005-06. This concept was pilot tested under the World Bank assisted National Agricultural Technology Project (NATP) from 1999 to 2005. The scheme aims at promoting decentralized, demand-driven and farmer-accountable extension system through a new institutional arrangement for technology dissemination in the form of Agriculture Technology Management Agency (ATMA). ATMA provides an institutional mechanism for coordination and management of Agricultural Extension System in the district. At the Block Level, the Block Technology Team (BTT - a team of Line Department officials posted in the Block) and Block Farmer Advisory Committee (BFAC – a group exclusively of farmers in the Block) are jointly responsible for operationalization of the Scheme activities.

Under the Scheme, sustained efforts are being made to provide fillip to major extension reforms such as bottom-up planning, broad-based extension delivery, involvement of multi-agency extension service providers, farmer-centric extension services and main-streaming gender concerns in agriculture by introducing innovative and progressive arrangements at different levels *viz.* State, District and Block.

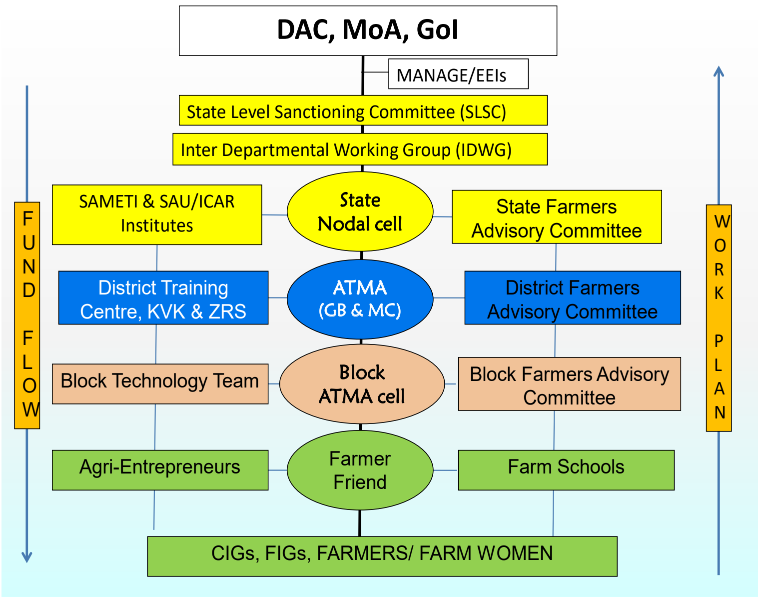
## New initiatives:

The following major initiatives have been taken during the 11$^{th}$ Plan:-

- Improving extension outreach by way of providing innovative support through a Farmer Friend (FF) at village level;

- Providing essential infrastructure support to State Agriculture Management & Extension Training Institutes (SAMETIs);
- Enhanced support for mobility and connectivity at district/ block level;
- Ensuring convergence with other Centrally Sponsored/ State funded schemes through approval of State Extension Work Planes by State Level Sanctioning Committees (SLSCs);
- Strengthening the farmers participation in planning and implementation through re-structuring of Block Farmer Advisory Committee (BFACs) and constitution of District Farmer Advisory Committees (DFACs) & State Farmer Advisory Committees (SFACs);

**Fig. 2: Institutional Mechanisms for Extension Reforms (ATMA) at National, State, District, Block and Village level**




## Extension initiatives of State Development Departments

**Andhra Pradesh:** The state has an innovative approach of identifying and involving progressive farmers to enhance the reach of extension services. About 41,000 Model farmers (Adarsha Rythu) have been identified for serving as crucial link between extension system and farmers. With coverage of 250-300 families per model farmer, effective coverage of farm families has been achieved. The state government has initiated a programme called Rythu Bata in an attempt to take the extension services to the doorstep of the farmers. Groups formed during Rythu Bata will perform as platform to create awareness about the ongoing Government programmes and to understand the problems being faced by the farmers. The

Mandal Agriculture Officer (MAO) visits the villages on fixed days and ensures spread of Knowledge and technology besides channelizing resources and inputs through these farmers groups. The date and time of village visit by the MAO is displayed prominently on the Black Board/Gram Panchayath office. Extension activities including exhibitions are organized during the meetings by involving ATMA, NGOs, KVKs, Rythu Sanghams and private organizations to generate interest and to motivate farmers.

Rythu Chaitanya Yatra (Farmers Motivation Campaigns) is another innovative approach of the state government to train the farmers on the technology gaps existing in their respective villages. This is being organized from the past seven years and it serves as a preparatory activity preceding *Kharif* season. This has given an opportunity to the extension personnel and scientists of agricultural university to reach every habitation/village and interact with farmers, educate them on the latest technologies in Agriculture and allied subjects and create awareness about various programmes and schemes.

**Bihar:** The state government has systematized the participatory planning and implementation of agriculture development activities. Marathon meetings and discussions with nodal officers, scientists and progressive farmers are held during February – March, followed by preparation of strategic plans by each developmental department. These plans are approved in the State Level Sanction Committee headed by Chief Secretary in April. The approved plans are shared with the implementing agencies at state and district level through workshops well before the commencement of the season. Krishi Utsav Raths and Krishi Utsav Shivirs (Agriculture celebration campaigns and camps) are organized in the month of May to mobilize and gear-up the farming community for adoption of latest technologies. Need based skill-building activities are arranged for all the farmers, particularly the resource-poor and late-adopter category farmers. Labour-first strategy has been adopted by the state government for bringing in most crucial changes like maintaining plant density and spacing in crops like paddy. The Transplanters' training has been a huge attraction and is turning out to be a game-changer strategy for achieving higher productivity within the available resources.

The state government has brought transparency in input distribution. Farm implements camps are organized every month so that farmers can visit these camps and purchase the implements of their choice and get the eligible subsidy amount in the same camp. Similarly the seed distribution camps are organized with the participation of all the seed companies.

**Maharashtra:** Maharashtra government has been promoting a concept of Farmer-Industry-Research-Extension (FIRE) for achieving Productivity-Quality-Returnability-Sustainability (PQRS). The five-point action strategy of the state to achieve this is as follows:

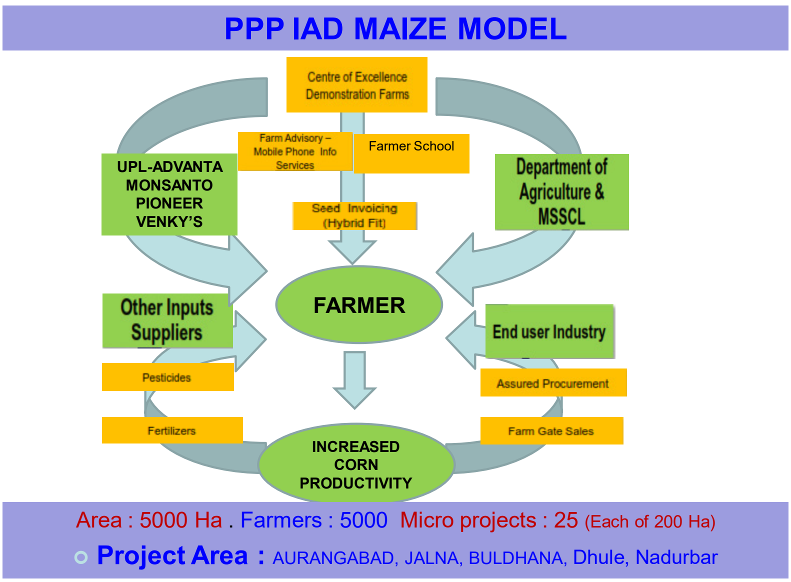
- Extension through organizing farmers into groups
- Extension through cadre of service providers

- Extension through Contract Farming
- Extension as a Part of Project implementation
- Public Private Partnership in extension

Public-private partnership for extension is gaining ground in the state. The primary objectives of the PPP in extension are;

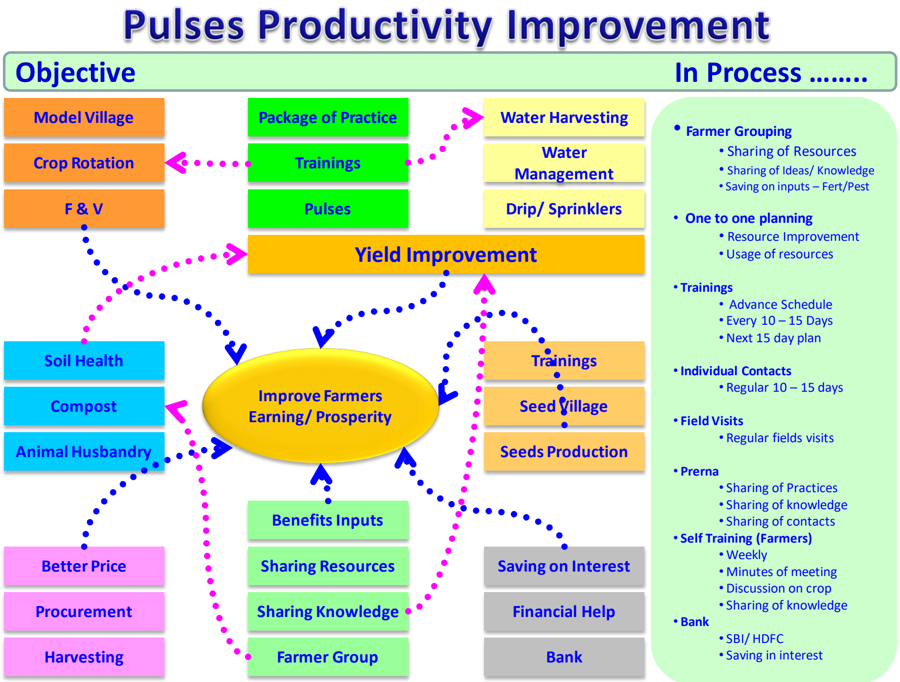
- Mobilise farmers into groups & federate groups into 'Producer Companies (PCs)'
- Implement end-to-end Extension Projects to develop crop specific value chains
- Demonstrate public/private technologies (e.g. seed and other inputs)
- Increase productivity by adopting best technologies in public and private sector
- Aggregate farm produce.

An example of a PPP model of extension is given below for maize crop. All participating companies have appointed dedicated district project teams and have excellent co-ordination with Govt. Extension Functionaries. Widely accepted drought tolerant genotypes (Hybrids) have been promoted in a project mode. The private players have specific roles. **Monsanto** has established Center of excellence on farmers' field through Farmers Field Schools and is providing voice mail crop advisories to farmers. **Pioneer** organizes joint village meetings & farmers trainings. **UPL** has established Unimart Farmers advisory centers. **Venkys** has obtained license for direct procurement from farmers & is in the process of opening procurement centers for farm gate purchase of end produce.




*Source: www.agricoop.nic.in*

Similarly the pulses productivity project is being promoted in a well-chalked out public-private partnership with Rallis India.




**Tamil Nadu:** The Tamil Nadu government has a multi-directional approach to extension. It aims at technology transfer through group approach, effective utilization of Farmer Friend provided under ATMA, handbook of programmes and schemes for the benefit of farmers and penetrative use of cyber extension. Technology adoption rate is being pushed through demonstrations, capacity building activities, exposure visits, exhibitions and mass media programmes. Technologies like SRI, SSI, SPI, Precision farming and micro irrigation have been promoted on large scale. These activities are strongly supported by requisite policy interventions like Uzhavar Peruvizha, Whole Village development programmes.

The state is planning for Mobile Enabled Computer Server Gateway programme for capturing baseline information of all farm holdings. This includes personal details, bank details, affiliation to various groups, land holdings, crops cultivated, source of irrigation, net income, plantation crops, farm animals, farm machineries, farm energy sources, micro irrigation facilities, apiary, fishery, sericulture and service requirement. This will serve as a platform for information retrieval by line departments while developing farmer oriented programmes.

Farm Crop Management System (FCMS) is an ambitious project of the government which aims at developing inventories of individual farms along with its fertility index so that suggesting best suited farm plan would be a possibility and providing technological options for higher productivity is feasible. With constant monitoring and technology support, the project aims at assessment of inputs/credit requirement, accurate forecasting of the quantum of output and accordingly providing market linkages for ensuring higher returnability to farmers.

## Extension through Krishi Vigyan Kendras (KVK)

The Indian Council of Agricultural Research established the first KVK in 1974 at Puducherry (Pondicherry) under the administrative control of the Tamil Nadu Agricultural University, Coimbatore. At present there are 631 KVKs (covering most of the districts of the country), which include 429 under State Agricultural Universities (SAU) and Central Agricultural University (CAU), 51 under ICAR Institutes, 99 under NGOs, 35 under State Governments and 17 under other educational institutions. Initially the ICAR mooted the idea of establishing Krishi Vigyan Kendras (Agricultural Science Centres) as innovative institutions for imparting vocational training to the practicing farmers, school dropouts and field level extension functionaries. However the KVKs have evolved over a period of time and today they are recognized as the only agricultural science institution at the district level and are playing crucial role in promoting climate resilient scientific agriculture. KVKs have created a niche for themselves as the frontline extension system performing the vital role of linking research - extension – farmers systems.

Krishi Vigyan Kendra scheme has been nurtured by ICAR and are expected to contribute to the growth and development of agriculture as they possess following unique features:

- Qualified and experienced scientific manpower spanning most of the agriculture and allied disciplines required for the district, thus making it a multidisciplinary agricultural science institution
- Instructional farm (20 ha) and demonstration units for educating farmers on latest developments in agriculture and allied sectors
- Infrastructure like farmers hostel and training facilities
- Complete funding support from ICAR
- Administrative support from respective host organization
- Strong support from district administration and development departments
- Technical back-up from Agricultural Universities and ICAR Institutes

The KVKs are working towards reducing the time lag between generation of technology at the research institution and its application to the location specific farmers' fields for increasing production, productivity and net farm income on a sustained basis. KVKs performance has been stupendous and impactful, particularly so, as they are working in tandem with the Agricultural Technology Management Agencies. The progress for 2011-12 revealed the following facts:

- Laid out 20015 trials to assess 2323 technological interventions in 3625 farmers fields to test the location specificity of technologies developed by the NARS
- Organized 104179 frontline demonstrations of emerging technologies on cereals, pulses, oilseeds, millets, cash crops, horticultural crops, animal husbandry, fisheries, food processing and value addition, farm mechanization etc
- Organised capacity building of farmers/farm women, rural youth and extension personnel through 65314 training programmes benefitting more than 18.80 lakh
- Organized 4,85,800 extension programmes/activities which attracted 107.16 lakh farmers and 2.61 lakh extension personnel. KVKs also organized 130015 extension programmes through electronic and print media in an effort to reach the unreached
- In their instructional farms, KVKs produced 1.74 lakh quintal seeds of improved varieties/ hybrids and supplied to 2.54 lakh farmers. Similarly, 206.59 lakh quality planting material of elite species of various crops were produced and provided to 1.60 lakh farmers. Bio-products were produced and supplied to the extent of 2.41 lakh quintals and 6.18 lakh numbers benefiting 15.27 lakh farmers. A total of 13,231 farmers were benefited by these livestock material produced and supplied by KVKs
- A total of 3.78 lakh samples of soil and water collected from 3.33 lakh farmers were analyzed and were given advisory service for appropriate nutrient and water management measures
- KVKs also sent 147402 short text messages to 11.14 lakh farmers in an effort to sensitise and advise the farmers to cope-up with emergent situations.

## Extension by Private Sector

Most of the seed and input companies have an element of extension (mostly embedded with the sale of their inputs or marketing of products) through their field workers. These companies also provide advisory services through their network of dealers and traders. An estimated three lakh input dealers sell various kinds of inputs related to farming and they provide product-related advisory services to farmers as part of their marketing strategy.

A few private companies have attempted 'one-stop farm solution centres' for furthering their extension services. Some of them are briefly mentioned here:

**Mahindra Krishi Vihar:** Mahindra and Mahindra Limited has established one-stop solution centres with the establishment of Mahindra Shubhlabh Services subsidiary, since 2000. The one-stop solution centres operate on a franchise basis and provide quality inputs, rent farm equipment, credit in partnership with banks, farm advice by trained field supervisors who visit fields, and arrange contracts with processors for off-take of crop produce. Dovetailed with the extension advice in this model are the distributorships and retailing of fertilizer and agrochemicals in partnership with the respective manufacturers.

**Hariyali Kisaan Bazaar:** DCM Shriram Consolidated Ltd. seeks to provide 'end-to-end agri-solutions' to farmers through these outlets built around a package of agri-inputs, extension, credit, and produce marketing services. These outlets have evolved over the years into a 'rural super bazaar' which also provide fuel, credit, insurance and mobile phones besides agri-related services, all under one roof.

Tata Kisan Sansar by Tata Chemicals Ltd. Has a franchise-based 'hub and spokes' model of outlets. The extension services offered by these one-stop shops include soil testing, remote diagnostics and house brands for seeds, cattle feed, pesticides and sprayers.

Godrej Agrovet has a chain of rural outlets and run in partnership with other companies to extend its product range. Its 'one-stop solutions' model offers agricultural equipment, consumer goods, technical services, soil and water testing, veterinary, financial and post office services, and pharmaceuticals.

**Jain Irrigation:** The Company has Jain High-Tech Agriculture Training Institute for training extension personnel on topics that include watershed management, water resources and irrigation management, fertigation and modern methods of crop cultivation. These trainings are offered to farmers, students, government department officers and NGOs who have interest in water management and irrigation related topics.

## Extension through Contract Farming:

A partnership arrangement between Rallis (supplies agri inputs and know-how), ICICI (provides credit to farmers), and HLL (the processing company) offers a buyback arrangement for wheat. Assured market and floor price for their wheat, timely supply of quality inputs and technical advice at no extra charge are the benefits to farmers. In turn, HLL enjoys a more efficient supply chain, while both Rallis and ICICI have an assured clientele for their products and services (Ferroni and Zhou, 2011).

PepsiCo practices contract farming in tomato, Basmati rice, chillies and groundnuts in Punjab, and potato in a number of states including Punjab. PepsiCo ensures technology transfer through trained extension personnel, and supplies agricultural implements free of charge and quality farm inputs on credit. In return, it obtains agreed quantities of quality produce from farmers at a pre-defined price. Contracted farmers also have the opportunity to manage risk associated with growing potatoes with a weather index based insurance product that is sold through ICICI Lombard and managed by Weather Risk Management Services. In potato, for example, the farmers are given six training of one day duration each at different stages of crop period. Each interaction is devoted on specific topic, for example sowing related aspects in the first interaction which covers selection of variety and seeds (micro-tubers), spacing, depth of sowing, use of tractor-drawn seed-cum-fertiliser drills, nature and quantum of fertilisers for basal dose etc. and initial irrigation.

## Extension by NGOs

NGOs such as BAIF, Basix and PRADAN operate in numerous states and have been active for many years.

**The Bharatia Agro-Industries Foundation (BAIF):** is senior-most among the three NGOs. A trusted disciple of Mahatma Gandhi Shri Manibhai Desai established the Bharatiya Agro Industries Foundation (BAIF), a non-profit, Public Charitable Trust in 1967 to replicate his experiences in rural development. BAIF has now been renamed as BAIF Development Research Foundation. BAIF is a Gandhian organisation committed to imparting livelihood opportunities to the rural underprivileged families. BAIF currently works in around 50,000 villages in 12 states of India. BAIF's areas of work include water resources development, sericulture, agro forestry, post-harvest product management and marketing, cattle feed and forage production. BAIF has more than 3,000 employees, including a strong contingent of scientists, and operates from 750 BAIF centres across India. The 'wadi' program to establish orchards, supported by soil and water conservation work on degraded land in tribal communities is one of its much acclaimed programmes. This program currently covers over 5,000 villages, benefitting more than 150,000 families in six states. BAIF facilitated the formation of farmers' cooperatives and federations of self-help groups. The national Vasundhara Agri-horti Producers Company Ltd. (VAPCOL) formed by these organizations supports its members in the development of products, processing and the supply chain.

**BASIX:** is a livelihood promotion institution working in 17 states, 223 districts and over 39,251 villages. The Holding Company of the BASIX Group is called Bhartiya Samruddhi Investments and Consulting Services (BASICS Ltd.) which started operations in 1996 as India's first "new generation livelihood promotion institution". It has a staff of over 10,000 of which 80 per cent are based in small towns and villages. BASIX strategy is to provide a comprehensive set of livelihood promotion services which include Financial Inclusion Services (FINS), Agricultural / Business Development Services (Ag/BDS) and Institutional Development Services (IDS) to rural poor households under one umbrella. Extension services for farmers is being provided for cotton, groundnut, soybean, pulses, paddy, chilli, mushroom, vegetables, dairy, goats and sheep rearing. The agricultural, livestock, and enterprise development services are made available by livelihood service providers, who work like extension agents for 200-400 customers each. According to Basix, its services reach around 800,000 farmers and involve productivity enhancement, risk mitigation, local value addition and alternative market linkages for synthetic inputs, bio-inputs and outputs.

**PRADAN (Professional Assistance for Development Action):** is a voluntary organization registered under the Societies Registration Act of India. Established in Delhi in 1983, PRADAN now has some 268 highly motivated and skilled professionals working in the remote villages of India. These professionals hold specialized degrees in subjects like management, engineering, agriculture, and the social sciences. PRADAN professionals, divided into 41 teams, work with over 206,298 families in 4,138 villages across eight of the poorest states in the country. A majority of the families that PRADAN works with belong to the Schedule Tribes and Schedule Castes. Its four-pronged strategy includes; (i) Promoting and nurturing Self-Help Groups (SHGs) (ii) Developing and introducing locally suitable economic activities to increase productivity and incomes among SHG members (iii) Mobilizing finances for livelihood assets and infrastructure from government bodies, donors, banks, and other financial institutions and (iv) Setting up mechanisms to sustain the livelihood gains made by the poor communities. PRADAN devotes a significant part of its intervention efforts on developing land and water resources. The aim is to enhance productivity, incomes and sustainable livelihoods. Towards this objective, PRADAN promotes the Integrated Natural Resources Management (INRM) of land, water, forest and biological resources to achieve and sustain potential agricultural productivity.

## Extension through ICT applications

**Kisan Call Centres (KCC):** To harness the potential of ICT in agriculture, Ministry of Agriculture took the initiative of launching an innovative scheme "Kisan Call Centers" on January 21, 2004 aimed at offering solutions to farmers' queries on a telephone call. These Kisan Call Centres (KCCs) are presently operating in 14 locations covering all the States & UTs with 278 Call Center Agents (CCAs) engaged therein answering farmers' queries in their language. Farmers from any part of the country can access KCC by dialing toll free number 1800-180-1551 from 6.00 A.M to 10.00 P.M. on all 7 days a week. This number is accessible through mobile/landline numbers of all telecom networks, even private service providers. DAC has also put in place a web based portal "*Kisan Knowledge Management System (KKMS)*", a database of State-wise Agricultural Package of Practices. Presently the database is available for most of the States for agriculture, horticulture, animal husbandry and fisheries, duly updated and validated by the State Agricultural Universities of the respective. The KKMS also has links to various schemes of the DAC, Ministry of Agriculture as well as weather related databases. The CCAs access KKMS over the internet, to find instant answer to queries from farmers. Every call is entered with details of farmers, query asked by the farmer and answer provided to him. Besides KKMS, Call Centre Agents go through standard books/publications of SAUs/ State Governments, browse Farmers' Portal & various Scheme Guidelines of DAC and material provided by the DAC for answering farmers' queries. The private service provider ensures that regular training/orientation of the CCAs in use of

KKMS application and availability of latest information/ literature on agriculture related issues pertaining to the State. At present, the IFFCO Kisan Sanchar Limited is the service provider of the KCC scheme. Till date, about 90 lakh calls have been received on the toll-free number. There is an increasing trend in the number of calls received as evident from the fact that more than 5 lakh calls have been recorded in the month of December 2012.

***aAqua*** ('Almost All Questions Answered') is an internet based discussion portal initiated in 2003 by the Developmental Informatics Lab of the Indian Institute of Technology in kiosks and cybercafés in Pune. A farmer can ask a question on aAqua from a kiosk or cybercafé; other farmers or experts view the question and reply (in English, Hindi or Marathi). The number of registered users was about 17,000 by early 2011. Poor Internet connectivity in villages and illiteracy appear to be among the conditions working against scale-up. The aAqua eAgriService is a problem-solving system dedicated to find solutions to problems posed by Indian farmers - small and large. The service is sponsored by support from Agrocom Software Technologies. Agrocom does not sell any kind of agri-inputs to farmers. Answers to agri-related queries are sent in 24 to 72 hours depending on the difficulty. Experts are employees of their respective organizations and serve without charge. One has to register with the forum to ask a question (no registration charges). Users can attach photos to helps illustrate their question. Files can also be attached. Anyone can answer aAqua Questions since the forum is open to all on the Internet. The user has to check the source of the answer. Answers from Public Extension Experts are marked with a Green Color Logo "Salahagar" in Marathi or "Advisor" in English, also shown as Certified Expert. Answers from Farmers and Private Experts come with the information they provided during registration. 72 Registered Experts form the expert forum - they come from diverse areas of expertise from KVK Baramati, ICRISAT, Pantnagar University and its KVKs, University of Dharwad and its KVKs and University of Raichur and its KVKs.

***Avaaj Otalo*** (literally, "voice stoop") is a voice-based system for farmers to access and discuss relevant and timely agricultural information by phone. The system was designed in 2008 as a partnership between UC Berkeley School of Information, Stanford HCI Group, IBM India Research Laboratory and the Development Support Centre (DSC), an NGO in Gujarat. The system itself is a Voice-XML based Interactive Voice Response system. When a farmer calls in, he/she hears audio prompts and is asked to enter a number from the keypad or say a word in order to navigate. By dialling a phone number and navigating through simple audio prompts, farmers can record and respond to questions, and they can access content assembled by experts. Roughly three times a week, over three thousand farmers get a phone call with a fresh message from DSC with information on dealing with the problems most facing farmers on that particular time of the growing season. They also can hear relevant agricultural news, event announcements, weather forecasts, market information, new government schemes, and more.

***Digital Green*** is a non-profit organization with funding from the Bill and Melinda Gates Foundation and the Deshpande Foundation. It disseminates agricultural information to small and marginal farmers through digital video. As per the details available at its website http://www.digitalgreen.org/ 2547 videos on agricultural techniques have been produced since operations started in 2008, which have been screened on 143769 times together benefitting 135685 viewers. Farmer groups and extension providers can access the library and use films sequentially to build farming capacity over time and as a learning resource in community interactive settings. Digital Green is partnering with large, well established organizations such as BAIF and PRADAN to carry out. It will be interesting to see how video as a medium is incorporated into, and is allowed to shape, the methods of extension of these and other organizations.

**IFFCO Kisan Sanchar Limited (IKSL):** emerged as a partnership between mobile operator Bharti Airtel and IFFCO (the Indian Farmers Fertilizer Cooperative Ltd) in 2007. Five free voice messages in local languages and customized for different jurisdictions are sent to subscribers every day, except Sunday. A 24-hour farmer helpline completes the service. IKSL markets this as part of a special mobile package on Airtel's network with an IFFCO Kisan branded SIM card for which farmers pay a one-time activation fee. The voice mail service is free, but helpline queries are charged at the rate of 1 Rs/minute. IKSL targets the millions of farmers that populate IFFCO's 40,000 member societies. On a cumulative basis, close to 3 million SIM cards have reportedly been activated; some 0.7 million farmers were active customers in late 2010. There is potential to go to scale in this partnership, which in its early days received a launch grant from the GSMA Foundation.

**Reuters Market Light (RML):** is a leading commercial information service provider for farmers via SMS in local language. The information includes local market prices, taluk-specific weather forecasts and crop advisories. RML is sold as an easy-to-use card (RML Direct) in several retail outlets in rural India. As per the information available in its website (http://www.reutersmarketlight.com/about_us.html) it offered price related information from 1300 markets spread over 13 states. It claims an estimated 1 million subscribers from 50000 villages and a total of 4 million farmers have been benefited through using and sharing.

***e-Choupal*** *is an initiative* by the agri-division of ITC Ltd, the Indian Tobacco Company. Each e-Choupal is equipped with a computer connected to the internet. A local person acting as a *sanchalak* (coordinator) runs the village e-Choupal. Farmers can obtain daily updates on crop prices in local mandis, procure seed, fertilizer, and other products including consumer goods, and sell their crops for prices offered by ITC. Launched in June 2000, 'e-Choupal', has already become the largest initiative among all Internet-based interventions in rural India. 'e-Choupal' services today reach out to over 4 million farmers ( as per data available in http://www.echoupal.com/frontcontroller.ech) growing a range of crops - soybean, coffee, wheat, rice, pulses, and shrimp - in over 40,000 villages through 6500 kiosks across ten states (Madhya Pradesh, Haryana, Uttarakhand, Karnataka, Andhra Pradesh, Uttar Pradesh, Rajasthan, Maharashtra, Kerala and Tamil Nadu). Real-time information and customised knowledge provided by 'e-Choupal' enhance the ability of farmers to take decisions and align their farm output with market demand and secure quality & productivity. While the farmers benefit through enhanced farm productivity and higher farm gate prices, ITC benefits from the lower net cost of procurement (despite offering better prices to the farmer) having eliminated costs in the supply chain that do not add value.

## Extension through Mass Media

**Mass Media Support to Agricultural Extension:** The "Mass Media Support to Agricultural Extension" scheme of Department of Agriculture and Cooperation (DAC), GOI, was initially launched on 21st January, 2004 and the revised scheme on 24.02.2005. The objective of the scheme is to disseminate information and knowledge to the farming community in local language/dialect for strengthening the agricultural extension system. Under this scheme existing infrastructure of Doordarshan and All India Radio is being utilized to make the farmers aware about modern farm technologies. Farm related programmes of 30 minute duration are being telecast 6 days a week through National, Regional Kendras (18) and High Power/Low Power Transmitters (180) of Doordarshan. Similarly, 96 Rural FM Radio Stations of All India Radio are being utilized to broadcast 30 minutes of programme for farmers 6 days a week. The Free Commercial Time (FCT) available under Krishi Darshan and Kisanvani programme is being utilized for dissemination of Advisories on *Rabi* / *Kharif* and popularizing the central scheme like contingency plan developed by State Governments and emergent issues like Drought, Flood credit and insurance, Kisan Call Centre, Kisan Credit Card National Food Security Mission (NFSM), MSP.

## New Initiatives:

- To ensure that the programmes being telecast are relevant for the particular season/crop and timely telecast of messages/advisories, besides the State Level and District Level Committees the following mechanisms are being put in place:-
    - o Constitution of "Technical Support Group" by the States under the Chairmanship of Director (Agriculture) to meet on a monthly basis
    - o Constitution of Agriculture Programme Advisory Committee in the Doordarshan Kendras under the Chairmanship of Station Director/ District Collectors.
- A Content Scheduling and Monitoring Portal were developed with the help of NIC to provide advance information to public at large on the schedule of programmes to be broadcast by DD/AIR during the month. The Portal is also being utilized for analyzing the programmes being broadcast for necessary corrective action.

- Increase in telecast of interactive programmes *viz.* phone in programme, reply to letters of farmers, quiz programmes on agriculture/veterinary, coverage of Kisan Rath Yatra etc. Doordarshan has made an innovative effort of organizing a series of 'Live Crop Seminars' involving farmers, officials of the State Department of Agriculture and Experts of all major crops for addressing the problems of the farmers.
- With the view to provide service oriented information to the farming community, Doordarshan has outsourced the production of programme on 'Agriculture News' and 'Mandi Bhav' to a private producer. Now the programme is also being telecast through 180 HPTs/LPTs transmitters, benefiting the farming community of remote areas.
- With a view to increase viewership and provide enhanced content to the farmers, the transmission timings of 'Krishi Darshan' programme telecast from 25 out of 27 Narrow casting Kendras where Regional Kendras are also functioning have been changed. Farmers can view the programmes telecast by both Regional and NC Kendras. This has benefited the farmers located in the range of 170 High Power / Low Power (HPT/LPT) transmitters who are now able to view 1 hour Agricultural programmes against the ½ hour programme which was earlier available.
- Focused Ad Campaigns: A number of Audio and Video spots have been produced for disseminating information on package of practices of Wheat, Pulse and Paddy and assistance available under the Scheme. The audio and video spots were telecast/broadcast under the Mass Media Scheme through Doordarshan during DD News, Regional news and DD Urdu, AIR during National news, Regional news and Rural Women's Programme (76 primary channels) and through 42 private channels operating at the National and Regional level during National News and 76 entertainment programmes.
- Community Radio Stations (CRS) would make a major contribution to agricultural extension by utilizing the reach of radio transmitter for disseminating information & knowledge produced locally or having relevance for a specific area. In order to give further boost to this initiative, it has been decided to extend funding of private institutions along with Government and Quasi-government organizations for setting up CRS.

**Community Radio:** The first documented case of CR being completely conceived, owned, run and sustained by a section of society (and used to fight poverty and social injustice) goes back to the Miners' Radios of Bolivia, Latin America. The miners' radios originated in 1949 with the birth of Radio Sucre in the mining locality of Cancaniri, while, at the same time, Radio Nuevos Horizontes started in the little city of Tupiza in the south of Bolivia. By the 1970s, the miners' radio network comprised 26 radio stations enabling workers, families and communities to communicate, discuss and debate their situation (UNESCO 2011).

In India, 1995 was a landmark year for Community Radio. The Supreme Court stated that airwaves are public property and must be used for the public good. Immediately after the Supreme Court judgment, civil society groups formulated the Bangalore Declaration, articulating the need for a third tier of broadcasting, i.e. community radio. This was followed up by the Pastapur Declaration in 2000 which re-articulated the need for community radio and also asserted that it ought to be non-profit making, localized and community owned. Between 1999 and 2001, several initiatives were launched in Karnataka (Namma Dhwani), Andhra Pradesh (Sangam Radio), Jharkhand (Chala Ho Gaon Mein) and Gujarat (Radio Ujjas), which used cable radio or bought time on AIR to broadcast local content.

In November 2006, the new policy allowed agricultural universities, educational institutions and civil society institutions to apply for a community radio broadcasting license under the FM band 88–108 MHz. By February 2012, there were 126 Community Radio Stations actively functioning across India. Some of the most popular ones are Namma Dhwani in Karnataka, Radio Bundelkhand in Madhya Pradesh, Vikalp CR in Jharkhand, Kumaon Vani CR in Uttarakhand, Radio Namaskar in Orissa and Radio Mewat in Haryana.

## Extension through Farmers Organizations and Agri-preneurs

**Agri-Clinics & Agri-Business Centres (ACABC)** is a Central Sector Scheme under implementation since 2002. The scheme promotes the involvement of agri-preneurs to supplement the efforts of public extension system by way of setting up of agri-ventures in agriculture and allied areas. Agri-Clinics are envisaged to provide expert advice and services to farmers on various technologies including soil health, cropping practices, plant protection, crop insurance, post harvest technology and clinical services for animals, feed and fodder management, prices of various crops in the market etc. which would enhance productivity of crops/animals and ensure increased income to farmers. Agri-Business Centres are commercial units of agri-ventures established by trained agriculture professionals. Such ventures may include maintenance and custom hiring of farm equipment, sale of inputs and other services in agriculture and allied areas, including post harvest management and market linkages for income generation and entrepreneurship development.

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is responsible for providing training to eligible candidates, through Nodal Training Institutes (NTIs) and motivating them for setting up of Agri-Clinics and Agri-Business Centres. The details of Nodal Training Institutes and the progress achieved are available in its website www.agriclinics.net. Till December 21, 2012, 31682 applications were received by MANAGE out of which 30558 candidates have already been trained under the scheme and another 581 were undergoing training. As many as 11482 of the trained candidates have established various kinds of enterprises in rural areas and are providing advisory services to farmers and are supplementing the efforts of the public extension system.

## New Initiatives:

- Revised eligibility criteria: In addition to Graduates in agriculture and allied subjects from SAUs/ Central Agricultural Universities/ Universities recognized by ICAR/ UGC, the expanded eligibility criteria include

  i Diploma/Post Graduate Diploma holders in Agriculture and allied subjects

  ii Biological Science Graduates with Post Graduation in Agriculture & allied subjects.

  iii Degree courses recognized by UGC having more than 60 per cent of the course content in Agriculture and allied subjects.

  iv Diploma/Post-graduate Diploma courses with more than 60 per cent of course content in Agriculture and allied subjects, after B.Sc. with Biological Sciences, from recognized colleges and universities.

  v Agriculture related courses at Intermediate (i.e. plus two) level, with at least 55% marks.

- The scheme covers full financial support for training and handholding, provision of loan and credit linked back ended composite subsidy as per the details given in the following section.
- Additional amount of 10% on food, accommodation, honorarium, training expenditure and handholding cost in NE and Hill States.
- Subsidy pattern has been revised from existing "capital and interest subsidy" to "composite subsidy", which will be 44% of project cost for women, SC/ST & all categories of candidates from NE and Hill States and 36% of project cost for others.
- Cost ceiling of projects is enhanced to Rs.20 lakh for individual's project and to Rs.100 lakh for a group project (minimum of five individuals).

**Mahagrapes** was born in 1991 with the valuable support of (a) National Co-operative Development Corporation (NCDC) New Delhi (b) Government of Maharashtra though its Department of Co-operation and Maharashtra State Agriculture Marketing Board (c) Agricultural & Processed Food Products Export Development Authority (APEDA), New Delhi and (d) National Horticulture Board (NHB), New Delhi. It is a Partnership firm of 15 co-operative societies, the main aim being to export grapes and other fresh produce to different parts of the world. Formation of co-operative societies has helped to reach every farmer. Each co-operative society is equipped with a pre-cooling & cold store facility; the technology imported from California which has proved to be an essential export tool. Every society receives day to day international market price and all the packaging materials required for exports.

The Board of Directors comprises of the heads of the 15 Co-operative Societies, of which seven have been nominated to an Executive Council. Two prominent and expert farmers from the executive council in turn have been nominated as executive partners to manage the day to day affairs. The Executive Partners are responsible for the decision making in the organisation. The Executive Partners are assisted by a team of Professional Managers. This team of professionals perform the delicate balancing act of locating internationally acceptable "Quality Product" on one hand & identifying the lucrative markets to increase net returns to its growers on the other hand.

**Producers Companies:** Producer Companies are the legal institutions, registered under GOI's Producer Company Act or Companies (Amendment) Act, 2002. It is a hybrid of Cooperative and Private Company Act, 1956. Members have to be necessarily primary producers, i.e. persons engaged in an activity concerned with or related to primary produce. Minimum 10 members must come together to form the producer company and there is no upper limit for number of members.

In Madhya Pradesh, 14 producer companies were established under the World Bank supported District Poverty Initiatives Project (DPIP). Each company received a seed capital of Rs. 25 lakh and annual contingency grant of Rs. 7 lakh by the State Government. Companies have been registered with the Registrar of Companies. Producers become members by buying at least 20 shares of Rs. 10 each. Trading of farmers' produce and agricultural inputs, seed production and marketing of major crops and varieties are the main activities of the companies. Company hires the consultants to provide advisory services to producers. Private firms interested in the product of companies also support the producer companies. Producer companies plan to tie up with corporates for farmer-retailer partnerships. Some producers companies also aim at having their own processing infrastructure, own identity, brands, supply chain, etc.

**Vegetable and Fruit Promotion Council Keralam (VFPCK):** is an ISO 9001-2000 certified company registered under section 25 of Indian Companies Act 1956 and has been established to bring about overall development of fruit and vegetable sector in Kerala. Established in 2001 as the successor organization of Kerala Horticulture Development Programme (KHDP), VFPCK is managed by a result oriented multidisciplinary team of professionals. VFPCK is a company with majority stake of farmers and the Government and financial institutions as the other major shareholders. Self Help Groups of farmers constitutes 50% of shares, Government of Kerala has 30% and other related institutions hold 20% of VFPCK's shares. The Primary objective of the Council is to improve the livelihood of vegetable and fruit farmers by empowering them to carry on vegetable and fruit production, value addition and marketing as a profitable venture in a sustainable way. It also aims to continue the successful activities initiated by Kerala Horticulture Development Programme. Promoted the concept of SHGs among horticultural farmers for their economic stability and better farming decisions. The Company has formed around 8025 SHGs thereby bringing under more than 1.55 lakh commercial fruits and vegetables farmers under its ambit in Kerala. VFPCK have initiated 274 farmer markets, a fruit processing unit and has developed farmer-friendly crop insurance packages for the benefit of horticultural farmers in Kerala. It has also developed a data bank of daily market prices and arrivals for the last 12 years of 40 varieties of vegetables and banana from 16 centers in Kerala and 4 from other states for market oriented production of vegetables and fruits and improved marketing decisions. The extension approach is marked with features like office-less extension, frequent farm and home visits by professionally qualified extension personnel and mass awareness programmes like campaigns, demonstrations etc.

**Farm School to promote Farmer-to-Farmer Extension:** Farm School under ATMA scheme is an attempt to institutionalize the concept of farmer-to-farmer-extension. Technical back-up from KVKs/Line Departments is ensured through-out the farm school period. These 'Farm Schools' are to be operationalized at Block/Gram Panchayat level and are set up in the field of achiever farmers who are the 'Teachers' in the Farm School. Leaders of Commodity Interest Groups (CIGs) formed in different villages and other farmers are the students/trainees at these Farm School. About six sessions/interactions are to be arranged, spread over the crop season/ enterprise cycle. One of the major activities of Farm Schools is operationalizing Front Line Demonstration, on any crop/enterprise that the achiever farmer has excelled in. Such a demonstration plot becomes the training ground for the entire season. This is an opportunity for the fellow farmers to learn from a farmer of their own and in an environment closer to reality and comparable to their own farms. Farmer-to-farmer extension would be a continuous process with the 'trainee farmers' own the responsibility of providing extension support to other farmers in the respective village or neighbouring villages.

## Extension Management Institutions (MANAGE, EEIs, SAMETIs):

National Institute of Agricultural Extension Management (MANAGE) at the national level, Extension Education Institutes (EEIs) at the Regional level and State Agricultural Management and Extension Training Institutes (SAMETIs) at the state level provide HRD support to state extension machinery. MANAGE was established in 1987 and has a vision to be counted among the most pioneering, innovative, farmer focused and self-supporting agricultural management institutes in the world. Its mission is to facilitate acquisition of managerial and technical skills by extension personnel, scientists and administrators in all sectors of agricultural economy to enable them to provide most effective support and services to farmers/fishermen for practicing sustainable agriculture.

Since as early as 1952, reforms in extension system has been brought into address the needs of agricultural development during different phases. Training and capacity building of extension functionaries was always given a priority status in the national extension system. Establishment of Extension Education Institutes (EEIs) was aimed at imparting higher training in extension education. EEIs were specifically established to meet the training requirement of extension functionaries on a continuing basis in the field of Communication Technology, Extension Methodology, Training Management, Participatory Rural Appraisal (PRA), Management of Agricultural Information System, etc. Four Extension Education Institutes (EEIs) have been established on regional basis. EEI for Northern Region is at Nilokheri and is functioning since 1959. EEI for Southern Region is located at Hyderabad and for Western Region at Anand and both are functioning since 1962. EEI for East & North East Region is located at Jorhat and is functioning since 1987. Their primary clientele are from state development departments.

State Agricultural Management and Extension Training Institutes (SAMETIs) have been established at the state level under ATMA scheme to strengthen the capacity building of state extension machinery, particularly for bringing extension reforms.

## Summary

India is a vast country and so its people and systems. Agricultural extension is no exception with its diverse stakeholders and pluralistic service providers, processes and approaches. Documenting all these is not only a herculean task, but is also impossible in a single issue. Hence this is just an effort to reflect the enormous subject through quintessential examples and a brief narration of the roles and activities under each example. The public extension system has been explained by reflecting on the centrally sponsored Extension Reforms Scheme (popularly known as ATMA), initiatives of four state development departments and the Krishi Vigyan Kendras of Indian Council of Agricultural Research. Private extension initiatives are numerous and varied in their nature. Contract farming is emerging as a time-tested extension approach of private companies. Application of ICT tools for extension is becoming a new feather in the cap of extension service providers. Private firms are vying with each other with all their imagination to exploit the potential of ICT tools. Mass media, particularly the Television channels of public as well as private sector are trying to have new programmes to attract the attention of farmers. Farmers companies, cooperatives and individual agri-preneurs represent the unorganised sector of extension service providers and are trying to fill the void that exists despite the huge presence of organised extension service providers.

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**Feed The Future India Triangular Training (FTF ITT) Program**

# International Training Program on “Climate Smart Agriculture”

**20th August – 3rd September, 2019**

**ICAR-Central Research Institute for Dryland Agriculture (CRIDA)**

**National Institute of Agricultural Extension Management (MANAGE)**

**Water and Land Management Training and Research Institute (WALAMTARI)**

| | |
|---|---|
| Number of Countries Nominated | **12** |
| Total Number of Executives | **27** |
| M: F Ration | **16:11** |
| Public: (Agriculture & Allied Sciences) | **23** |
| Private: (Private Companies) | **3** |
| Civil Society: (NGOs, Cooperatives) | **1** |
| **Total** | **27** |

| Country | No. of Executives | Country | No. of Executives |
|---|---|---|---|
| Afghanistan | 2 | Kenya | 1 |
| Cambodia | 2 | Malawi | 2 |
| Nepal | 5 | Mozambique | 2 |
| Sri Lanka | 6 | Uganda | 2 |
| Myanmar | 1 | Tanzania | 2 |
| Botswana | 1 | Liberia | 1 |
| **Total** | | | **27** |

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